THE PRACTICAL ASSAYER.

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THE

PRACTICAL ASSAYER

CONTAINING

EASY METHODS FOR THE ASSAY OF THE PRINCIPAL METALS AND ALLOYS,

Principally designed for Explorers and those interested in Mines

BY OLIVER NORTH.

WITH ILLUSTRATIONS AND TABLES.

London:
CHATTO AND WINDUS, PUBLISHERS.
1874.

PREFACE.

My object in writing this book has been to provide a want I long felt myself—that is, a concise and clear account of the best and quickest way of assaying the principal metals. I think most works on this subject mix up the province of the analytical chemist too much with that of the assayer, whereas the two are totally distinct. Analytical chemistry presupposes, as a primary condition, that the operator should be a chemist; whereas assaying is a mere mechanical art, depending almost entirely on manipulation; so that the very first chemist of the day might easily be far inferior to a good assayer in estimating the exact value of an ore. Indeed, some of the very best and quickest assayers I ever knew have been Chileno and Mexican youths, who could hardly write their own names; and yet their manipulation and knowledge of mixtures, from constant practice, was perfect. Perhaps the very finest manipu-

lators and quickest operators in the world are the natives employed in the Indian Mint. I have consequently left out all hard words and formulas, and also some better processes than those given, as I have wished only to recommend those methods which are at once easy of execution, useful to the explorer, and do not necessitate the use of expensive apparatus.

I have added the estimations of guano and nitrate of soda, as these substances are now playing such an important part in commerce.

In an Appendix I give a description of the Guayacan method of smelting copper, a method which has been the subject of much contention.

I recommend all my readers to get Fresenius's "Handbook of Quantitative Analysis," as well as Church's invaluable "Laboratory Guide" To this latter gentleman my thanks are due for much valuable information in regard to the assay of guano, and also to the Editor of the *Mining Journal*, for permission to reprint the Smelting articles.

LONDON, *March* 16, 1874.

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THE PRACTICAL ASSAYER.

ASSAY OF COPPER.

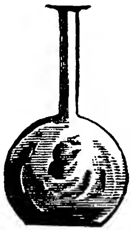
In the following pages all description of the assays of copper by the dry way has been omitted, for the following reasons. They are rough and uncertain, inaccurate in their results, and never give the true result even by the most careful manipulation. The roasting process is an extremely tedious one, and even then desulphurization is rarely complete: if too much flux is employed, portions of the copper are retained in the slag; if too little is used, an impure copper is produced. The assay requires a very high temperature, often unprocurable in some out-of-the-way places; and, moreover, in poor classes of ore the

results are totally at fault. Both silver and gold are liable to get collected in the copper product, both of which must be eliminated by a separate process. The dry method, no doubt, is exceedingly advantageous to buyers and owners of smelting works, as, although ores are purchased on a different scale from those assayed by the wet process, yet there is no room for doubt that the balance is always most decidedly on the side of the buyer.

I shall, therefore, proceed at once to the description of the "precipitation process," as practised almost universally in Chile. The Chileno assayers have brought this process to a really surprising degree of accuracy, and for cleanness, quickness, and correctness, it leaves nothing to be desired. This method is pursued in the large laboratory of Guayacan works in Chile, and I am under great obligations to Mr. Cosgrove, the assayer at that establishment, for much of the matter contained in the following descriptions.

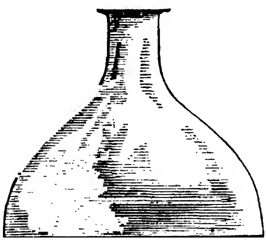
APPARATUS, &c., REQUIRED.

Some flasks, similar to that marked No. 1, for boiling the acid solution. Some precipitating flasks, similar to that marked No. 2.



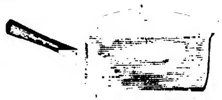
No. 1.—Best shape of boiling flask, of Bohemian glass, 8 or 10 oz. capacity. The sharp shoulders prevent spurtings.

Some iron-wire, of the thickness of a goose-quill. Porcelain capsules, with handles and



No. 2.—Precipitating flask of best Bohemian glass. Capacity about 1 pint.

covers, No. 3. A few glass rods, and some



No. 3.—Porcelain capsule for washing the precipitated copper. Capacity 1 pint.

large porcelain evaporating dishes, about twelve inches diameter.

METHOD OF ASSAY.

We will suppose the operator has received five samples to be assayed: he will proceed as follows.

Mark the packets in order, on the top corner, thus, 1, 2, 3, 4, 5, before opening them. Take five boiling flasks, well cleaned, and mark them with corresponding numbers, with pen and ink. Turn up your balance, to see if it is in order, and then weigh out 100 grains from each packet, and place them in the several flasks. [N.B.—If the ore is rich, say over 40 per cent., 50 grains is sufficient.] Fold up the packets again, and shut down the balance. If the ore contains sulphur such as copper pyrites, &c., pour in about three teaspoonfuls

of pure nitric acid, and set the flask to stand for a few minutes till the violent ebullition ceases, when it may be placed at a very gentle heat, just sufficient to keep it at the boiling point. If we were sure that the ore contains no sulphur whatever, it would be unnecessary to use so much nitric acid; but it is always best to use a little, even in ores supposed to be free from sulphur. Proceed in like manner with all the flasks. In about a quarter of an hour or more, according to the hardness of the ore and the amount of sulphur it contains, it will commence to be "attacked," that is to say, the sulphur will be observed floating on the top in a black globule. Heat may be now cautiously applied, when the globule gradually "cleans" itself and becomes of a bright yellow. If very unattackable, it may be necessary to add a few more drops of nitric acid, in order to perfectly clean the sulphur, or, in other words, to render it quite yellow. The contents must now be dried off to a paste, and about two or three teaspoonfuls of pure

muriatic acid added. The solution may now be dried off gradually and evaporated to dryness. The best way to accomplish this is to seize the neck of the flask with the tongs, and work it with a circular movement on the sand-bath, so as to get the pasty mass as it were plastered around the sides of the flask: by this means the nitric acid is more effectually driven off than if the contents were left to stand upright in one position. A very good plan, when the contents are dried, is to bury the flasks completely in the sand-bath, placing them in an inclined position, to prevent spurting, and heaping up the hot sand over them up to the muzzle. Seize the flask with the tongs, introduce a small glass tube, and *gently* blow off any nitrou s fumes that may remain: the very gentlest breath is sufficient to effect this, as a sudden puff might blow out particles of the copper contents. When the flask is cool, add another two teapoonfuls of muriatic acid, and evaporate to a thin paste; then add a little boiling water, and allow to

settle in an inclined position. Should any portions of the ore stick to the side of the flask, the boiling water will remove it; if not, a few minutes boiling on the sand-bath will effect it. The same process having been gone through with all the flasks, the operator now places on a table, close by the sand-bath, five of the flasks for precipitating (No. 2), and places in each a filtering glass about three inches diameter. Moisten the filters first with boiling water, and then filter the solutions. The best way is to pour in about half at first; wash down the filter with a few drops of boiling water after it has nearly passed through, and then pour in the other half, taking care to leave as much of the residue behind as possible. Wash this residue once or twice with hot water, and add to the contents of the filter, and allow the whole to filter through. Then work your filter *down from the top* with a circular motion of your wash-bottle filled with boiling water. To make sure you have left no copper behind in

the residue in the boiling flask, add to it a few drops of nitric acid, and then a drop or two of ammonia; if copper is present, a blue colour will appear. Take the filtering papers out and place them on one side, corresponding to the numbers on the flasks, in a warm place near the edge of the sand-bath, to dry. The copper must now be precipitated as follows. The five numbered flasks are placed on the sand-bath to warm gradually, and three or four pieces of iron-wire, about four inches long, are cut off by a pair of sharp pliers. Care must be taken that the ends of these wires are smooth and not jagged, or they might hold minute pieces of copper. Wrap them up in a piece of paper three or four folds thick, doubling the ends over so as to form a small packet. Five packets must be prepared in this way. Place these small packets on the edge of the sand-bath, or any other hot place, until you judge they are somewhere about the heat of boiling water. The object of the paper is, of course, to prevent the wire from

becoming blackened. The solution in the precipitating flasks may now be heated to just the boiling point: take them off the sand-bath and place them on the table. Now take one of the packets of wire, break off one end of the paper envelope, so as to expose the ends of the wire, and, holding No. 1 flask in an inclined position, slide the wire into the solution, taking care not to let the wire fall heavily in, or it might break the flask. Do the same with all the others. The flasks must now be left to stand for some little time. When the wires are thickly coated with copper, the flasks may be gently shaken, which will detach the copper and expose the wire afresh to the action of the acidulated solution. When the solution is nearly colourless it is better to add about three or four drops of muriatic acid, and give it a boil up for a few seconds only on the sand-bath, to extract the last particles of copper. It may be known when all the copper is precipitated by immersing a piece of bright iron-wire in the solution occa-

sionally near the end of the operation. Directly the copper is precipitated the flasks must be removed from the sand-bath and placed on a table in order, with five capsules numbered accordingly. A large kettle of boiling distilled water is placed on the operator's right hand, who proceeds as follows.

Take flask No. 1, and pour off into the capsule as much of the supernatant liquor as possible, leaving the wire and copper behind. If this is carefully done, this first part may be thrown away. Now pour some boiling water (not too much) into the precipitating flask, allow to settle, and pour off again: this also, if carefully done, may be rejected; but, if particles of copper come over, must be retained. More water is added to the flask, and the whole contents of it transferred to the capsule, taking care to leave no specks of copper behind. The flask may be put aside, and the same process be repeated with the other four. The iron-wire must be now cleaned off with the tips of the forefinger and thumb,

and thrown away. It only remains to wash the copper. Opposite each of the five capsules place one of the large evaporating dishes, with a glass rod. Half fill the capsules, one after the other, with boiling water; stir up with the glass rod, allow to settle, and pour off into the evaporating dishes. The test of good pouring is to leave as much copper as possible in the capsule, and to pour over as little as possible into the large dish. After three or four washings, add a *few* drops of muriatic acid to the water, and allow to stand for three minutes. This is to remove any iron that may be present. Pour off, and in the next washing put two drops of muriatic acid, and drop in a drop of a weak solution of ferro-cyanide of potassium. If iron is present, a blue colour is produced; but if, on the other hand, a faint pink colour is produced, it is a sign that too much acid has been used, and a small portion of copper dissolved. This latter error should never occur, and, when it does, a small allowance only must be made

for it, as it is very trifling. If iron is present, the washing must be continued till it is eliminated. After the last addition of acid, three washings are generally given to render the copper perfectly clean. The copper in the evaporating dishes is now to be washed once or twice, and added at once to that in the capsule. The whole is now drained off as dry as possible, and nothing remains but to dry and weigh it. *The drying is accomplished thus:* When the copper in the capsule is drained of its water, it will, of course, have collected at the edge in the bottom, in a way inconvenient for drying: by holding the capsule, however, with the spout away from you, and inclined to the ground slightly, and giving the bottom, under the collected copper, a smart tap with the fingers of the right hand, the copper will jump, or rather slide, on to the middle of the capsule, spread out in a thin layer. A little practice with wet sand will soon enable anyone to accomplish this. All draughts must be now excluded, and the capsule

placed on the sand-bath at a *gentle* heat. Five minutes will generally suffice to dry the assay. This may be known by gently pressing the top of the copper with the point of a knife; if not dry, it yields gradually to the pressure; but if dry, it comes off in scales. The covers are now placed on each, and they are taken to the balance-room, and weighed as quickly as possible, by taking out one of the copper pans of the balance, and brushing the contents of each capsule into it with a fine camel's-hair brush. The difference in weight gives the percentage. The whole operation generally takes about one hour and a half; but a practised assayer can perform it in a quarter of an hour less time. It is not advisable for one assayer to attend to more than five washings at one time, and, where many assays are taken, the assistant is employed during this time in attacking and filtering the others. It is a very good plan, where many assays are taken, to weigh out the samples overnight, and leave them in a slightly warm place till the morning, when they

will be found to be ready for filtering. At the large laboratory of Guayacan as many as twenty or more of these assays are taken daily, with only one assistant, besides thirty or forty cyanide assays. The results by this method are most exceedingly correct, when performed by a good operator. In an assay of a valuable cargo of Chile ore, three assays are sometimes taken as a check, and they generally come out within half a tenth per cent. of each other when done by the same assayer. A tyro will invariably get *low* results, the loss occurring principally in the washing.

OBSERVATIONS ON THE ABOVE METHOD.

Although this method is most extremely exact, still considerable practice is necessary, and the following observations, for many of which I am indebted to Senor Domeyko, of the University of Chile, are impressed upon the reader.

In attacking the ore *always* use muriatic

acid, and it is best always to use nitric acid in case there is some sulphur in the ore. When sulphuric acid is used, much white residue is formed, which sticks to the side of the flask, and the latter frequently breaks. To avoid this accident, and to complete the dissolution of the ore, let the assay get cold, and then add water gradually until all the white residue is dissolved.

Generally speaking, it is necessary to attack till the residue is white; but sometimes the residue is black silicate or graphite. When this is the case, the assay may be considered as finished when a fresh dose of acid produces no effect, or we may test it by the blowpipe or cyanide. The operation of evaporating to dryness being troublesome, and liable to loss of oxide of copper in case the residue is heated too much towards the end of the operation, it may be omitted sometimes, provided that the filtered liquor passes off perfectly clear, and with excess of acid. Complete evaporation should, however, always be had recourse to if gela-

tinous silex appears during the boiling with acids: this substance sticks to the flask, and frequently causes spurtings and projections. In case we suspect that some silex has been precipitated with the copper, we dissolve some of the dried and weighed copper in acid, to see if any residue remains. It is, however, far better *always* to evaporate to dryness, both to make sure of getting rid of all traces of nitric acid, and to completely dry the silex and render it quite insoluble. Never attack a sulphurous ore too quickly at first: if you do so, the sulphur takes up some portion of the cupreous matter, envelopes it, and renders its extraction extremely difficult. It is better to let it digest at least twenty minutes, at a gentle heat, before moving the flask. Of course, the less sulphur the ore contains, the quicker the operation of attacking can be pushed forward. Should the ore be extremely difficult to clean, and the operator in a hurry, it may be effected by repeated small doses of nitric acid and drying off to a thick paste on the sand-

bath; but it is always best to let the ore digest and clean itself.

In filtering, do not employ too large a filter, as that necessitates extra washing. Take care to well wash the upper edge of the filter, and always wash from the top to the bottom. The object of drying the filters on the sand-bath is to see whether any cupreous solution has been left on them: should this happen, of course the copper will leave a stain on the filter. This is one of the most fruitful sources of error with beginners. Generally speaking, it is better to let the filtrate run nearly through before adding more or washing down.

The solution in the precipitating flasks must have a certain degree of concentration, in order that the copper may be precipitated in thin *leaves* and not in fine powder, which it would be if the solution was too weak. This fine powder floats on the top, and gets both oxidized and lost; and, besides, the precipitation takes place slowly and is not complete.

The wire ought to be of the same tem-

perature as the solution, more or less: if the wire is too cold, the first copper precipitated sticks to it, and prevents the rest from being thrown down. The wire must be of the very best quality, and not liable to chip, or else minute portions come off in the acid solution, and are subsequently weighed up with the copper. It is better to test every fresh batch of wire before using it. Remember not to keep the iron in long after the copper is precipitated, or an excess of salts of iron is formed which is very difficult to wash out. Seven or eight washings are generally required for each assay. The first washing comes off clear, and the next two come off red and turbid, producing specks, some of which float on the top, and some mix with the precipitate: this results from the facility with which the salts and subsalts of iron are decomposed. While the liquor remains acidulated, as always happens at the beginning of the operation of washing, this decomposition does not take place, but afterwards it does. A few drops

of muriatic acid are added to dissolve these subsalts of iron. If the precipitation has been carefully conducted, one addition of acid will be sufficient, if allowed to stand a few minutes.

After weighing, the capsules must be examined; if quite, or very nearly clean, the assay has been carefully conducted as far as the washing is concerned, but if the iron and acid has not been washed out, a yellowish-black stain will be observed round the place where the copper was dried, deeper in proportion to the quantity of iron. In this case allowance must be made for the extra weight of the iron, which some assayers can estimate to a nicety. Speaking generally, it would require a very deep stain to warrant a reduction of 3-10ths, and 1-10th usually suffices.

If the assay substance is very rich, we may prevent in a great measure the annoyance of having an excess of iron and acid in our solution by the following method. When it is judged the precipitation is nearly com-

plete, take out the wire and clean off the copper; put it (the wire) into another evaporating dish, and pour the nearly exhausted liquid into it; add a few drops of acid, and boil up, to extract the lost particles of copper. Throw away the liquid, and wash the few grains of copper into the flask with the rest. The great bulk of the copper is thus preserved from the injurious effect of the salts. This, however, will not be necessary after the operator has had a little practice in estimating the proper strength of the solution. To put it plainly, the solution ought to stand about half an inch in height in the precipitating flasks for an ore of 20 per cent.

In spite of all precautions a small portion is sure to pass into the state of protoxide, but this gain in weight is compensated by a small loss in metal which remains in the solution unprecipitated.

I have been purposely exact and quite plain in my description of the above process, as it is the one undoubtedly most suited to the

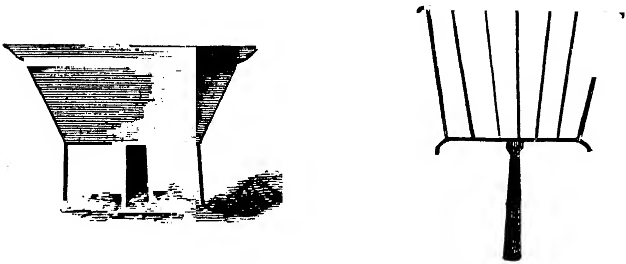
requirements of the general practical assayer. and is at the same time the most reliable and exact. It has often been condemned for its slowness, whereas, when well conducted, twenty or twenty-five assays can be made by one assayer and an assistant. It requires no heat beyond that of an ordinary kitchen fire, and possesses the great advantage of cleanliness.

I shall now proceed to describe a modification of this process, suited to those assayers who may not have access to a large sand-bath, or who are engaged in exploring, &c. As many as four assays at once can be taken by the following method, which is even quicker and preferable (for a small number of assays) to the method with a sand-bath.

APPARATUS REQUIRED.

The same as for the preceding operation, with the exception of a *brazero*. This consists of a large iron dish about twenty inches wide on top (rim and all), and fourteen inches wide at bottom. A flat rim runs round the

top, two inches wide. In the bottom are three or four holes, half an inch in diameter, and the whole thing is supported on four legs four or five inches high.



Nos. 4 and 5.—Brazero and gridiron for taking four copper assays simultaneously.

A sack of good charcoal; a pair of small cork-armed iron tongs for the flasks; a common gridiron, with four legs, of such a size that the legs are supported on the rim of the brazier; two halves of a brick and a tile or two, complete the apparatus.

The first thing to do is to light a charcoal fire in the brazier and wait till it has quite burnt out to white ashes. When about half full of ash another fire is to be built on the top of it, and the brazier is always to be

kept half full of ashes. They make one of the best sand-baths in the world.

Having made the fire, place the gridiron on the rim, and your flask or flasks on the top of it. If the fire is too hot, or the ore too hard to be attacked quickly, place a piece of thin tile under the flask, which will moderate the heat. When the assays are cleaned off from sulphur, the gridiron is removed and the assays placed round the fire, while they are one by one evaporated to dryness by means of the cork-armed tongs. An assay can be dried off much quicker by this means, and a good flask never breaks through contact with the hot embers.

The gridiron must be replaced for the filtering, precipitating, &c.; the precipitating flasks can be subjected to a gentle heat by placing a brick or a thin tile under them, according to the degree of heat required. The wires when required to be heated can be placed at one of the corners of the gridiron. Four assays can be taken in this way at the

cost of about *2d.* for fuel, and quicker than on a regular sand-bath. Indeed those Chileno assayers who only have four or five assays to do, prefer the *brazero.*

Señor Domeyko advises for precipitation small bars of iron three inches long by half an inch square. These bars must be slightly curved so as to rest on the tips, exposing the whole surface to the action of the acidulated solution. One advantage in this method is, that the copper comes off in half-inch leaves, making it much easier to wash, and not being so liable to waste. The great disadvantage is that the bar is liable to slip and break the flask. A pair of ivory or bone-tipped tongs must be used to introduce the bar into the flask. Some assayers dispense with the precipitating flask altogether, filtering the solution direct into the capsule, and precipitating the copper also in the same vessel. It is better to use a flask, as the copper solution splashes up on the side of the capsule, and it is not so easy to manipulate as a flask.

Although the above process is sufficient for all purposes that a practical assayer is likely to require, still we may as well give the two following accounts, condensed from the *Chemical News.* The first is for the assay of sulphurous ores, as copper pyrites, by Mr. F. P. Pearson; and the second, for the determination of minute traces of copper, by Mr. J. M. Merrick.

Weigh out 100 grains of the ore, and a teaspoonful of chlorate of potassium, and place the mixture in a porcelain dish. Add enough nitric acid to cover the ore; heat gently on a sand-bath, and add from time to time small doses of chlorate of potassium and nitric acid till free sulphur is no longer visible. Allow the solution to become cold; add hydrochloric acid, and evaporate to dryness, to render the silica insoluble. Add water to the cold solution, and transfer the contents to a beaker. Heat the contents to boiling point; prepare a strong solution of ferrous sulphate, slightly acidulated with sulphuric acid, and

add to the boiling solution 25 c. c. of this latter, and keep it just on the boil for five minutes. If the reduction is not complete, add cautiously a little of the ferrous solution until the contents of the beaker become almost black, and no gas is disengaged. In order to be sure that all the nitric acid has been reduced, it is better to test a drop with ferricyanide of potassium. Filter the liquid into a beaker, and precipitate with iron in the usual way.

It is claimed by Mr. Pearson that by this method the last traces of nitric acid can be removed more quickly and conveniently than by successive doses of muriatic acid, and that the chlorate of potassium oxidises and dissolves every particle of the sulphur, so that no ore can be enveloped and escape decomposition. I very much doubt whether the method is quicker. The great point in the process described first is to let the assay stand at least twenty minutes at a *gentle* heat, and not boil strongly at first. If this is attended to, the sulphur is perfectly bright and clean at

the end of half an hour. On the whole, I do not think this latter process is any way preferable to the Chile one.

Mr. Merrick's process is as follows:

Dissolve the ore in nitric acid; evaporate to dryness, and heat the residue to render silica insoluble. Add boiling distilled water and ammonia to precipitate and redissolve the copper. Filter, wash, and add sulphuric acid. A stout platnum wire is now hung in the solution, and the copper is plated out on the inside of a platinum dish which forms the cathode of a battery of two small Grove's cells. For the estimation of very small quantities of copper no method can approach it.

If nickel is present it can be determined in the same manner, by rendering a sulphate solution ammoniacal with excess of ammonia. There are many other methods of assaying copper ores by precipitation, but as they are either too long or involve use of apparatus which the ordinary assayer is not likely to be able to obtain, they are omitted.

ASSAY OF COPPER ORES CONTAINING ROUGH OR NATIVE COPPER.

Sometimes in a sample of ore there remain on the sieve particles of copper which will not pass through. The estimation is effected as follows:

The *whole* sample is first weighed: say it equals 5000 grains. Now weigh the rough copper; say it equals 3000 grains. Consequently the ore and gangue equals 2000 grains, thus:

Total sample	=	5000 grains.
Rough copper	=	3000 grains.
Ore and gangue	=	2000 grains.

Now assay the rough copper as usual—say it gives 98 per cent.: also the ore—say it gives 50 per cent. of copper. So we have

3000 grains × 98 per cent.	=	294,000
2000 grains × 50 per cent.	=	100,000
		394,000

Now divide this product, viz., 394,000, by the

total weight of the whole sample, viz., 5000 grains, and the result is the correct per-centage of the ore. In the present case, of course, it amounts to $\frac{394{,}000}{5000} = 78{\cdot}8$ per cent.

In assaying bar copper or ingots, great care must be taken to get a correct sample. The best way is to empty the packet into a porcelain mortar, stir it up well with a spatula, and then let it fall on a sheet of glazed paper through a wide funnel. Then take your sample by smoothing down the top of the pyramid thus formed, and taking a few grains from here and a few from there. It is always best to take two assays of bar or ingot copper. In these assays always use dilute nitric acid at first, or else the very violent ebullition that ensues might carry off some minute particles of copper. In assaying copper slags, the flask or flasks must be continually kept in motion, to prevent the substance sticking to the sides, in which case a long time is wasted in boiling it off again.

ASSAY BY MEANS OF STANDARD SOLUTIONS.

Of all the methods that have been proposed to assay copper ores by volumetric analysis, only one, the cyanide of potassium method, is unobjectionable. Some are too tedious, some inaccurate. The cyanide assay is both quick, easy of execution, and accurate; consequently, this is the only volumetric method that will be described.

APPARATUS, &c., REQUIRED.

Some boiling-flasks, similar to those used in the precipitation process.

Some graduated burettes, of 1000 grains capacity, divided into twenty equal parts of ten divisions each, or two hundred divisions in all. The burettes made by Messrs. Jackson, of Barbican, are especially suited to this purpose.

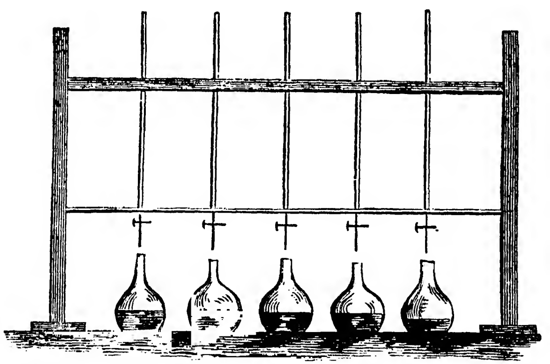
Some black india-rubber tubing, glass jets, and pinch-cocks, for the above.

Some cyanide of potassium: the crystallized cyanide sold by Johnson and Sons, London, is

by far the best for this purpose. It is purer, takes up much less bulk in travelling, and is much clearer in solution. Its relative price is about the same as the ordinary cyanide. The most convenient and the cheapest way of arranging the burettes is as follows:

Get two square uprights of common deal, and two pieces of wood four inches wide, and thirty inches long, one being half an inch, and the other one-eighth of an inch thick. Cut two square holes at each end of these pieces, and fix the thinnest one about seven inches from the bottom of the square uprights, and the thickest one near the top, two or three inches less than the length of the burette. At the bottom of the uprights may be nailed two square pieces of lead as stands. Five holes, the size of the burettes, must be bored in the upper slip of wood, and five corresponding ones, but of much less diameter, in the lower. To arm the burettes, cut off three inches of india-rubber tubing, and screw one end on to the end of the burette previously moistened in

the mouth, and fix one of the glass jets into the other. Three inches is quite sufficient, as too long a piece "flops" about, and scatters drops of the solution. The burette may now be slipped in at the top hole, and the point of the burette passed through the smaller one. The burette is prevented from passing quite through by its shoulder resting on the edge of the hole. The pinchcock may now be attached, and the apparatus is ready for use.



No. 6.—Method of arranging five or more burettes.

The cyanide solution is made by dissolving such a quantity in pure distilled water as shall be equal to a given quantity of pure copper.

As, however, it is best to be exact in descriptions of processes, I shall take five grains of copper as the standard, to equal which about two thousand grains of ordinary cyanide are placed in a large green or blue ammonia bottle, and the latter filled with water; the liquid is filtered if necessary. Of course some cyanide is stronger than other. To prevent the decomposition of the salts, a fluid-ounce of ammonia is added to the solution of cyanide. Suppose five samples are to be assayed, the operator proceeds as follows:

The packets of ore are to be numbered as before, and six boiling-flasks are taken and marked correspondingly.

A piece of the purest electrotype copper that can be obtained is cleaned in dilute nitric acid, dried, and weighed roughly on a balance to within a fraction of five grains. It is now weighed on the most accurate balance obtainable exactly to five grains. The most convenient form of pure copper for this purpose is sheet or leaf copper. A per-

fectly clean boiling-flask is taken, and the piece of copper dropped in. A small quantity of dilute nitric acid is now added, and the copper is dissolved. A few drops of water are added, and the solution boiled to expel nitrous fumes. It is cooled in a bucket of water, and the flask filled one-third full of water, and made *quite* cold. Three or four teaspoonfuls of ammonia are now added, when a deep-blue solution is the result. If not quite cold, dip the flask in cold water, or, still better, let a tap of cold water run over it. This forms the *test* assay. Weigh out twenty-five grains of ore (or twelve and a half grains, if very rich) from each packet, and place them in the corresponding flasks. Add about two teaspoonfuls of nitric acid, and digest till the ore is quite decomposed: dry off, moisten with nitric acid, dilute with water to half the flask and add ammonia in excess. Wait till the assays are quite cold, and then proceed as follows:—

Shake up the bottle of cyanide solution to render the contents homogeneous, and pour out

into a common milk-jug a pint, more or less. Rinse out the burettes by running a little cyanide through them ; then place the pinchcocks on, and fill them all up to the very top, taking care not to let any run down the outside. Wait till all the bubbles rise to the top, and then let the liquid gradually fall down to the level of the zero. Two portions of the liquid will be observed, like the convex and concave sides of a crescent. It is better always to read the burette from the *lower edge* of the circle, and not from the tips of the crescent. Some assayers employ a "reader," but this is quite unnecessary.

Take your pure copper solution, and run in from a burette seven divisions, more or less; agitate the solution well, and allow it to stand for five minutes. Now add two more divisions; agitate and allow to stand again ; and so on, two divisions at a time, until about eighteen divisions are run out. The ammoniacal solution begins now to assume a purplish hue, and the cyanide must be added, a few drops at a time,

till a decided lilac tinge is produced. The operator must be careful now, and when only a faint lilac tinge is left, the assay is finished. This tinge ought to disappear, and the solution appear quite white in about ten minutes after the last addition of cyanide. About twenty minutes is the best time to be consumed in getting the required tint. In a burette of twenty divisions, this tint ought to be obtained as near as possible at the twentieth or last division. A piece of folded white paper, placed under the flask, greatly facilitates the estimation of the colour. The ore solutions are now taken and placed under their respective burettes; the cyanide solution is added, say four divisions at first. The bottles are well agitated for at least a minute, a circular twirl given, and the contents allowed to settle. The deepness of the blue colour is now observed, and, according to its depth or faintness, the cyanide is added slowly or quickly. After each addition of cyanide the contents of the flask must be well shaken, to make sure of all the copper being

taken up. When a faint lilac tinge similar to that of the pure copper test is obtained, the assays are finished.

Supposing that the pure copper solution required exactly twenty divisions of the cyanide to decolorize it, and No. 1 of the ores required seventeen divisions, the per-centage of the ore may be read off according to this formula :—

$$
\begin{array}{l}
20 : 5 :: 17 \text{ in } 25 \text{ grains of ore.} \\
 \underline{17} \\
20)\overline{85} \\
 4.25 \\
 \underline{4} \\
17.00 \text{ per cent. of copper.}
\end{array}
$$

This saves all trouble of calculations, &c. The solution may be got very easily to this standard by adding either water or cyanide, according to its strength, and, as it is subject to a very slow decomposition, a large quantity, like an ammonia bottle full, need only be tested once a week.

Any number of assays can be taken by this method in half an hour.

REMARKS ON THE ABOVE PROCESS.

The above method, simple as it appears, is most extremely difficult of execution by an inexperienced operator, who may easily make an error of two or three per cent. This arises from a variety of reasons.

Nitrate of copper produces a pure blue, but sulphate and chloride of copper communicate a lilac and greenish hue respectively. It is better not to make use of either hydrochloric or sulphuric acid in dissolving the ore. After an assay has stood some time, it occasionally assumes a greenish hue, not arising from the presence of foreign metals. In this case add a few drops of nitric acid and a teaspoonful of ammonia, and agitate.

The more ammonia that is used, the more intense is the colour, and a great excess of ammonia sometimes causes a greenish blue tinge to be observed. *Only just sufficient*

ammonia is to be added as will cause the solution to assume the blue colour. Solutions poor in copper, such as slags, &c., nearly always assume a greenish tinge.

Nickel, cobalt, manganese, and zinc interfere with this method of assay.

Manganese may be removed by the addition of carbonate of potassa, when present as oxyde. The solution must be heated and filtered from the precipitate.

Jacquelain says that the addition of white pulverized marble to the solution until all action ceases, and then warming the solution in a sand-bath, renders the presence of nickel and cobalt quite harmless. The solution is now filtered, washed, the residue dissolved in nitric acid, and treated with ammonia as before.

Instead of using ammonia fortiss it is recommended to use as the ammoniacal agent a saturated solution of carbonate of ammonia. Great care must be taken in adding this liquid, as the bubbling and effervescence are very violent. The foreign metals are neutralised to

a great extent by this means, but a very fine precipitate is formed, which takes a long time to subside ; this prolongs the determination of the last few tenths of the cyanide solution. It is always advisable not to filter the ore solution if possible, as washing the filter greatly increases the bulk of the ammoniacal liquid. Indeed, in all assays, transferring from one vessel to another, either by decantation or otherwise, is greatly to be guarded against.

It is far better, however, on perceiving the presence of the interfering metals, to reject the solution altogether, and assay the ore by the precipitation process.

Zinc, in small quantities, does not seriously affect the accuracy of the assay, as may be easily proved by one or two experiments on copper precipitated by means of zinc. A large quantity, however, interferes with the decolorization.

Oxyde of lead produces a slight milky tint to the solution : this rather facilitates than disturbs the final estimation.

BLOWPIPE ASSAY.

A few grains of the ore are finely pounded up, and carefully roasted in a small porcelain dish over a spirit-lamp. A small quantity of phosphor salt is melted on the platinum wire, and dipped into the powdered ore; the whole is now fused into a bead. Repeated doses of bisulphate of potash are added to the bead, until the latter is saturated. It is ground in the porcelain mortar, and the contents rinsed into a small evaporating dish, and dissolved in boiling water. It can now be tested with ferrocyanide of potassium. If copper is present, a red precipitate is produced. If a very small quantity of copper only exists in the ore, a brown precipitate is thrown down; and if no copper, and only a small quantity of iron is present, a bluish-green precipitate is exhibited.

The phosphor salt is added for the purpose of making the effect of the bisulphate of potash more effectual.

This method is peculiarly applicable in cases where the explorer wishes to detect or suspects the presence of copper in minute quantites in iron pyrites.

Red and black oxyde of copper, the carbonates blue and green, give the usual indications with the borax bead, and a metallic *globule on being reduced with carbonate on* charcoal.

Copper pyrites and grey copper cannot be distinguished by the usual borax and charcoal tests. The former can be distinguished by its being softer than iron pyrites, with which it is often confounded, by its forming a blue solution with nitric acid, and giving off an odour of sulphur before the blowpipe flame.

In the case of the carbonates, the estimation by the blowpipe may be most effectually made as follows:

Choose a piece of charcoal free from cracks, and scoop out a small hole in the side. Make up a mixture of one part of the mineral to be tested, and four parts of carbonate of soda,

forming in all a piece the size of a pea. Place it in the hole, and very carefully direct the blowpipe flame upon it; when the piece appears settled, the reducing part of the flame may be directed upon the bead, and as hot a blast as possible kept up. When the metal is obtained as a globule in the charcoal, the assay *is finished. Extremely rapid* and accurate results may be obtained by this method.

Supposing a mineral is suspected to contain copper in small quantities, say five per cent., a good way to proceed is as follows (this method of assay cannot be applied in the case of pyrites):

Mix a little of the ore with carbonate of soda, and place the mixture on a sound piece of charcoal. Add soda till the charcoal has absorbed the whole mass; cut out the surrounding charcoal and assay piece, and grind up the whole in the agate mortar with water; decant off the charcoal, and grind alternately, till all the extraneous matters are rejected. If any copper is present, even in

minute quantities, it will be seen in small flakes coating the mortar, or settled at the bottom in fine powder. Great care must be taken to thoroughly reduce all the metal in the assay piece, by keeping up the flame to its highest pitch, and attacking every part of it, and also in decanting the ground charcoal and flux.

The black and red oxydes, and the carbonates blue and green, can be easily distinguished by the above tests. Grey copper and copper pyrites, however, give no indication either with borax or carbonate of soda.

The detection of copper by borax colouring the bead is as follows:

The end of the platinum wire is bent into a loop, and a small piece of borax fused on it: more borax is added, and so on till the loop is filled with a bead of fused borax. This bead is then heated gently, and dipped in the powdered mineral to be tested, and kept in the oxydising point of the flame, in as hot a flame as possible, for some little time. The colour imparted must be watched, both when the bead

is hot and when it has cooled. If no colour is imparted, a fresh supply of mineral may be taken, but if the borax is completely saturated with the colour, so as to be dull, the experiment must be repeated with a smaller quantity. The bead may then be placed in the reducing part of the flame; care, however, must be taken, in this latter case, not to allow the bead to cool too suddenly, or it would become oxydized. A good plan is to place it in the flame of the blowpipe lamp for a few moments and cool it gradually.

If copper is present in the mineral, the colour of the borax bead will be *red* in the reducing flame, and green and blue, when hot and cold respectively, in the oxydizing flame.

ASSAY OF SILVER.

ALL silver ores may be assayed in three ways. 1. By running *them* down *in* a crucible with a *suitable flux.* 2. *By* scorification. 3. *By the* blowpipe. *We will take the three* processes *in* order.

1. Running down the ore with a flux.

Minerals composed of copper and silver can be assayed either as silver or as copper ores, as the lead button that is obtained from the fusion with litharge is capable of being cupelled if it has a suitable proportion of lead to the copper.

In the case of argentiferous regulus coming under the operator's notice, the mineral must be roasted previously. Metallic lead might be added as the lead-producing flux, but it is always preferable to use litharge free, or nearly free, from silver as the agent. It is easily mixed and disseminated through the mixture.

The most convenient reducing agent is char-

coal, reduced to the finest possible state of division. The fusing fluxes most commonly used, and also the most convenient, are carbonate of soda and borax.

The four substances—viz., litharge, carbonate of soda, borax, and charcoal—are all that are required for any silver ores that are likely to fall under the notice of the practical assayer, with the exception of galena, the assay of which will be described separately.

The first thing to do is to assay the litharge. To do this, take 1,000 grains and place them in a large warmed crucible, with 200 grains of carbonate of soda, and 35 or 40 grains of charcoal; intimately mix with the spatula, and cover the whole with a layer of carbonate. Fuse at a low heat, and when fluid pour out the contents into a mould, and reserve the button of lead for cupellation.

The amount of silver must be noted, and the corresponding amount deducted from the actual assay. Having determined this, proceed as follows:

Place two crucibles to warm over the cover of the furnace, and, meanwhile, weigh out the following mixture:

Ore . .	100	grains
Litharge .	400	,,
Carbonate	350	,,
Borax. .	150	,,
Charcoal .	20	,,

Intimately mix the whole on a sheet of glazed paper, and shoot the mixture into the warm crucible; shake the contents even, and take 50 grains or so of litharge on the point of a spatula, and powder over the top of the contents. Prepare two crucibles in this manner. Place the crucibles in the furnace, side by side, and pack the coke round them till they are completely enclosed. Take off one of the bricks at first from the top of the furnace, and fuse at a low heat *at first*, winding up with a full red heat for five minutes, to thoroughly fuse the slags: the whole operation is complete in about twenty or twenty-five minutes.

The great point to be observed in this part of the process is to keep the heat as *low* as possible at first, as silver lead is sensibly volatile at a high temperature.

When the contents of the crucible, which can be viewed through a small chink between the bricks, flows quite smoothly without bubbling up, the crucible must be seized with a pair of furnace tongs, tapped once or twice on the side of the furnace to settle the contents, and poured immediately into a hot mould, previously rubbed with common blacklead to prevent the lead sticking to it. Allow the mould to stand for five minutes, and then invert the contents into a bucket of cold water. Allow to cool, and the slag will then come off with one or two taps of a hammer on the edge. The slag detaches itself much easier if the button is plunged into cold water before it is quite cooled. The lead button must now be cleaned by holding it edgeways on an anvil and tapping it gently with the hammer, occasionally dipping and cleaning it in water.

Hammer it into a thick cube, and scratch on it the corresponding number of the packet sent to assay, and set it aside for cupellation. If the ores should contain antimony, &c., the button may come out brittle, and perhaps break up under the hammer; if so, clean the button as carefully as possible and place it in a scorifier, and add about half its weight of granulated lead and scorify as usual, to be hereafter described.

The above mixture will generally suffice to run down most of the silver minerals that are likely to come under the assayer's notice, though, of course, the quantity of lead must be varied according to circumstances, as in argentiferous regulus and galenas. Sometimes, when the ore is very hard, the flux will not flow smoothly, but appears viscid and thick. In this case some mixed borax and carbonate may be placed in a copper shoot and projected into the crucible, and the heat urged on for a few minutes.

Argentiferous Regulus is assayed as follows:

Calcine the ore first "sweet," or quite free from sulphur. Take 100 grains of the ore, and add the following mixture:

Litharge .	1000	grains.
Carbonate	350	,,
Sand . .	100	,,
Borax . .	150	,,
Charcoal .	35	,,

Intimately mix with the usual precautions. The sand is added to prevent the large quantity of litharge from attacking the pot, as it attacks the sand instead. A double quantity of litharge is added, in order that the excess of lead in the button may pass the copper contained in the regulus into the cupel. If a small quantity of lead, or, in other words, a small button, was cupelled, the copper would be so concentrated that the assay would not yield a silver button, but a silver and copper one, owing to there not being sufficient lead to pass the copper. This will be treated of presently under the description of the assay of

alloys. If there is a difficulty in procuring borax, the same quantity of green bottle-glass answers the same purpose.

Galena, or Silver Lead, is assayed in precisely the same manner as if it was being assayed for lead only. The two following methods are the best, and, if carefully performed, very little lead is lost:

No. 1.—Ore	. .	400
Carbonate		350
Borax	.	50
Argol	.	30

Intimately mix, and cover the top with some of the mixed carbonate and borax. Then take three large nails, or, better still, three pieces of hoop iron, and push them down to the bottom of the mixture in a triangular shape. Place the crucible, iron and all, in a furnace, and fuse at a low heat for twenty minutes. Give about two minutes' strong heat at the end, during which you can remove the pieces of iron one by one, tapping them and washing them in the

molten metal, to prevent globules of metal sticking to them. Then pour as usual.

No. 2.—Ore	. .	400
Argol	. .	100
Carbonate		400
Borax	.	200

Mix and cover as before; add the pieces of iron, and proceed exactly the same as in No. 1. If carefully performed, both these methods yield excellent results, particularly the first one. Of course, if the galena is extremely rich, half the quantity of ore may be taken, and the requisite proportion of granulated lead added to the assay.

SCORIFICATION.

We are enabled by this process to obtain an alloy of lead capable of being cupelled. The principles are exactly reversed; for whereas in the crucible assay the object is to reduce the oxyde of lead to a metallic state, in the process of scorification the metallic lead is oxydized by being roasted in contact with the

air. Scorification is the most convenient, cheap, and correct way of assaying silver ores, when properly performed.

METHOD OF ASSAY.

The scorifiers should not be of the usual shallow shape, but deeper in proportion to their width: in fact the best form of scorifier may be compared to the end of an egg. The object of having them this shape is that the bath of molten lead at the bottom is always covered and protected by the slags on top during the whole process of roasting. The scorifiers should be well dried before using them for the assay. Proceed as follows:

Mix 300 grains of granulated lead with 50 grains of the ore to be assayed. Place the mixture in a scorifier, and cover over with 300 grains more of granulated lead: over the whole put as much borax (anhydrous) as you can, and place the scorifier in the strongest heat of a good muffle for at least thirty minutes. If the slags are not liquid, add a little more borax, and

urge on the fire for ten minutes more. When the slags are quite liquid, which generally occurs in about forty minutes, wrap up four or five grains of powdered anthracite in a piece of paper, and drop it into the scorifier while in the muffle. Wait till the anthracite has burnt off, which will be in about five minutes, and then pour immediately into a mould.

The object of adding the anthracite is to reduce any metal that may exist in the slags, and thus save the trouble of assaying the slags subsequently.

In case the operator has a chloride of silver ore to assay, carbonate of soda must be added to the mixture, to prevent sublimation.

In case argentiferous regulus is the substance under consideration, 1000 grains of granulated lead must be employed to the same quantity, viz., 50 grains, of the ore.

Generally speaking, about ten or twelve times the amount of lead is required, but galena scorifies with a very much smaller proportion, three or four parts being sufficient. Very often

it happens that the contents of the scorifier will not start roasting, but the slag sticks and does not uncover; this arises from the furnace being too cold; a little glass of borax wrapped up in paper and dropped in generally sets the assay going. When borax is used the slag surrounds the metal like a ring, which is continually diminishing, and at last the whole bath is completely covered with liquid slag: the fire ought then to be pushed on to its hottest. There ought always to be sufficient lead left to form a slag, which completely covers the button when this latter is poured out. There is no difficulty in performing this method of assay; the great points are to have the furnace hot enough, and not to pour the contents out until they are quite liquid.

When poor ores are under treatment, the crucible method is the best, as only 50 grains can be used in the scorification process, and, consequently, unless two assays are taken simultaneously, the resulting button of silver is small; but when very rich ores, and more

particularly rich *copper* ores, are operated upon, scorification is very useful, as in the crucible method much copper is reduced with the lead, so that a very large quantity of lead is necessary in order to pass the copper into the cupel.

The muffle cannot well be too hot for this operation: the right heat is when you can just see the back of the muffle whitish. The most common fault is having the muffle too cold.

Supposing that the operator has to determine the silver contents of copper regulus; the best way of proceeding is as follows:

Warm two scorifiers; weigh out 50 grains of the regulus into each, with 1000 grains of granulated lead and some borax: scorify as usual, and pour. Place the two buttons thus obtained in a fresh scorifier, and scorify till they are completely covered with fused oxyde. Then cupel the resulting button.

CUPELLATION.

This operation depends on the property a cupel has of absorbing the oxyde of lead produced during the operation, leaving only the gold and silver remaining.

The first thing to do is to thoroughly dry the cupels, which can be conveniently done by placing them in the furnace while it is heating: if not thoroughly dry, the contents of the cupels will spit, and project portions of the metal out on the floor of the muffle. They are best placed topsy-turvy when drying. When the muffle is at a cherry-red, *and no hotter*, they can be turned right side upwards, and the buttons introduced one by one. Close the door of the muffle to start the buttons, or make them uncover; occasionally they will not uncover for some time. In this case a piece of thick brown paper placed on the top, or a piece of burning coke generally suffices to start them. When they are well started, open the door of the muffle and allow

the cupellation to proceed at *as low* a temperature as possible. When the brightening takes place, close the door and give a good strong heat for a minute or two to disengage the last traces of lead from the button. Take hold of the cupel with the tongs and draw to the mouth of the muffle, and allow the bead to cool gradually. If it is a good-sized bead, and the cupel is taken too suddenly from the muffle, the silver cools more quickly on the surface, and, contracting on the outside, squeezes the liquid metal inside, which forces a way out for itself. When this happens, the bead is said to "vegetate." Supposing that the bead has cooled satisfactorily, take hold of it with a pair of close pincers, and examine it. If it is round, bright, and white above, crystalline below, and easily detached from the cupel, the assay may be considered to have passed accurately. It is now to be strongly squeezed with the pincers, which will have the effect of detaching all particles of the cupel which would otherwise adhere to it. A cupel ought to be 30 or 40 grains heavier

than the button to be assayed. The button does not represent the actual amount of silver in the ore, as a loss, greater than that in the large way, invariably occurs in cupellation. This loss arises principally from volatilization and absorption into the cupel. The first may be partially prevented by taking care not to cupel at a higher temperature than is absolutely necessary; and the second by attending to the quality and texture of the cupels. These losses, however, if the operation is carefully conducted, are not counted in commercial assays.

By the colour of the cupel after the operation is finished we may judge of the foreign metals contained in the mineral. Lead gives the cupel a sulphur colour; copper, a dirty-brown shade; bismuth, an orange-sulphur. Tin and iron give a black and grey slag, which stands like a ring round the edge of the cupel. Zinc leaves a thick sulphur circle, and gives off dense white fumes, and occasionally spits and bubbles. Antimony very frequently cracks the cupel; in this case,

as before stated, the button must be scorified with rather more than half its amount of lead, and then cupelled.

ALLOY OF SILVER AND COPPER.

The determination of this alloy is estimated by cupellation. The chief point is, as in the case of regulus and rich copper ores, to have sufficient lead to pass the copper into the cupel. In case we are uncertain what the quantity of copper is, we can be sure of succeeding by using from twelve to fifteen parts of lead, which is the quantity required to pass pure copper. For the assay of standard silver—a florin, for instance—about six times the amount of lead does very well; but it is always better to add a little more, and make sure. An alloy of $\frac{900}{1000}$ silver requires about eight times the amount of lead; $\frac{600}{1000}$ of silver, about twelve times; and, after that, about fourteen or fifteen times the amount, up to pure copper. It is best to make a rough assay first of all, if the

standard of the alloy is not known, by cupelling 5 grains of the alloy with about 50 grains of pure test lead, and noting the loss of weight in the resulting button.

The actual assay can be made as follows:

Weigh off twelve grains of the alloy on the most delicate balance that is at hand; then calculate the amount of lead requisite for the passing of all the copper, and place part of it (the lead) in a cupel in the furnace, with all the precautions already pointed out. When the lead is well fused, wrap up the piece of alloy in the rest of the lead, and drop it in the molten metal. Cupel as usual, and reserve for weighing. Now weigh off twelve grains of silver that is standard. Put about sixty grains of lead in a cupel, and cupel the silver as usual. Then weigh both the buttons. If they both weigh exactly alike, the alloy is standard. If it is 1 dwt. less, it is called 1 dwt. less than standard; if more, it is called 1 dwt. more than standard.

In large works it sometimes occurs that

copper bars or ingots may contain silver; with so large a quantity of copper it is inconvenient to cupel.

The mode of assay is best performed as follows:

Weigh off three pieces of about fifty grains each, and place them in three scorifiers, with the usual precautions; scorify to the extreme limit, and place them altogether in another scorifier; scorify again as usual, and cupel the resulting button. Of course borax must be added as usual, as well as six hundred grains or so of pure lead. All native silver, that which remains on the sieve during the sieveing of rich ores, rough silver, &c., may be all most conveniently assayed by the above scorification method.

Alloys of platinum, silver, and copper are not likely to fall under the every-day assayer's notice, and are therefore unnoticed.

Assays of alloys of silver and gold will be noticed under "Gold Assaying."

LEAD TABLES FOR SILVER CUPELLATION.

1000	parts	of fine silver	require about	3	times	of lead.
950	”	”	”	6	”	”
925	”	”	”			
900	”	”	”	7	”	”
850	”	”	”	9	”	”
800	”	”	”	10	”	”
700	”	”	”	12	”	”
600	”	”	”	14	”	”
500 or less		”	”	17	”	”

In gold assays, about *double* the above quantities of lead are required.

GENERAL OBSERVATION ON THE ASSAY OF SILVER ORES.

All silver, and especially gold ores, which contain a large proportion of sulphur or arsenic or antimony, should be roasted. In the case of sulphur there is danger of oxysulphurets forming and conveying portions of the noble metal into the slag along with them. No particular care is required in roasting ores. The best way to effect it is to half-fill two cruci-

bles with the ore, and place them on the top of the coke in the reducing furnace, or in a common fire, and keep continually stirring the ore with an iron rod. Roast slowly at first, and, after no more dense fumes are given off, heat the contents to a dull red heat, till they are quite "sweet." If much arsenic or antimony is present, a little finely powdered charcoal is added to reduce the arseniates or antimoniates.

In the case of galena, which, of course, is very fusible, some fine sand had better be mixed with the ore previous to roasting.

In scorification it is best to give not too strong a heat at the *commencement.* At first the ore will be seen floating about on the top like a small island; when this disappears and is melted, the slag rises to the top and encircles the bath of molten metal like a ring. During this period the heat ought to be raised, and may be still further increased to the end of the operation. About sufficient borax to well powder over the mixture must be added

at first, and, if the fusion seems to stick, a little more must be added in a piece of paper. It is as well to add a small piece of glass of borax at the end of the operation to thoroughly fuse the slags.

In cupellation a button of lead about three hundred grains in weight is the best size for operating upon. In case the button of silver is very large, great care must be taken in cooling it, else it will "spit."

The proper heat for cupelling is when the assay just passes well and no more: towards the end of the operation the heat may be increased. It is generally recommended to prefer a high heat and quick cupelling to a low heat and a lengthened one. This is a great mistake, as silver in conjunction with lead is sensibly volatile at a high temperature. The poorer the button is in silver, the higher the temperature may be kept, as there is obviously less silver to volatilize.

Occasionally the button stops, or, as it is called, suddenly "freezes:" this is nearly

always due to too little heat being employed in the furnace, but of course never happens with ordinary care. If it does happen, unless great haste is needed, always cupel afresh. Some assayers close the door of the muffle when cupelling, but it is always better to have the door partly open during the operation.

On detaching the button, if it comes off extremely easily, and is bright below, it is sure to contain lead, and should be rejected. If, however, it is flat and not rounded nicely, it has not had sufficient lead.

In running down ores in the crucible method, care should be taken not to employ too much charcoal; otherwise the slag comes out black, and retains portions of the silver. One part of charcoal to twenty-five of litharge is the best proportion in ordinary cases. It is always best to powder over the top of the contents of the crucible with litharge, in order that the rain of melted lead may pass through the contents and take up every particle of silver contained in the ore. Directly the con-

tents of the pot cease bubbling, and flow smoothly, they ought to be poured into the mould. If the borax boils up, the crucible must be lifted gently out, tapped once or twice on the side of the furnace, and cautiously replaced. It will soon subside.

REMARKS ON THE OPERATION OF CUPELLATION.

The furnace must not be too hot nor too cold. If the heat is high, silver is volatilized, and the pores of the cupel open and absorb minute portions of the metal. If the heat is too low, the button would be sure to retain minute quantities of alloy or lead. It is difficult to give exact prescriptions for the regulation of the heat; but if the fumes of lead rise straight up to the top of the muffle, the heat is too high, and the cupel must be moved nearer to the door. If, however, the smoke falls to the bottom of the muffle, the heat is too low, and the cupel must be moved further inside the muffle. But we may judge more

exactly of the necessary heat by observing the colour in that part of the cupel which has just been left by the bath of lead. If this appears of a dull reddish colour, the assay is at the right temperature. If the cupel is of a white-red, the heat is too high, and if it is almost black, the temperature is too low. When the assay is half-way finished, it is better to pull it slightly towards the door of the muffle, and, when nearly finished, to place it at the back, and close the door of the muffle. The button appears dull for some time after it has ceased giving out the rainbow colours, and all of a sudden "brightens." In order that the assay may be correct, the time between this dulness and the brightening should neither be too long nor too short. This time varies with the heat of the furnace and the texture of the cupels. Assays of alloys of $\frac{900}{1000}$ generally require about thirty seconds to produce this brightening, while those of $\frac{200}{1000}$ only require about ten seconds. In very compact cupels the brightening shows itself with great facility,

and very quickly; but in this case it is requisite to finish them with a high temperature.

When a larger proportion of lead is used than is required, the assay experiences a considerable loss from being so long in the muffle. If, however, the lead is in too small a quantity, the alloy will retain portions of copper, and the result will be inexact. Buttons that have been cupelled with a great excess of lead nearly always vegetate; they do not shine brilliantly, and are nearly round instead of presenting a hemispherical shape: they, moreover, adhere very slightly to the cupel. The assays, on the contrary, that have been cupelled with too little lead do not brighten, and produce buttons with black patches of oxyde of copper on their surface: the buttons also adhere very strongly to the cupel. As has been already stated, the time of the brightening must not be too long, nor too soon after the disappearance of the rainbow colours. When the brightening appears too soon, a round button is rarely obtained: on its surface are seen

lustrous and also some dull white spots : the button adheres but slightly to the cupel, and sometimes has small needle-like holes below, which is a sign that it has not had enough heat at the finish. When, however, the brightening is too long in appearing, the button which is obtained is of an uniform dull white, with black patches of oxyde of copper on its surface, and some small depressions : it adheres very strongly to the cupel, is black below, and frequently vegetates.

The signs of a good button are the fact of its being round, lustrous, and crystalized below, easily detached from the cupel, and white on the bottom.

Galena may be assayed by submitting it to a direct cupellation, even when the substance contains 2 or 3 per cent. of pyrites or blend. We may effect this without adding lead at all ; but there is danger of the sulphate of lead which is formed covering the bath, *impeding* the oxydation, and adhering to the button of silver. It is, therefore, better to add lead in

the proportion of 3 or 4 per cent. Galena has a remarkable tendency to throw out sparks when submitted to heat, and we must, therefore, grind it to a very fine powder in an agate mortar. A few grains are taken, enveloped in a sheet of lead, and introduced into a cupel in a good hot muffle, and the door closed: the instant the mineral fuses, the sub-sulphate which is formed swims on the top of the melted lead. As soon as the contents have acquired the same temperature as the cupel, the muffle is opened, and air admitted, but cautiously, or else particles of mineral are sure to be projected from the bath of lead. Much smoke now arises from the cupel, and the surface of the bath appears covered for some time with a solid convex film or crust, which gradually settles down and gets thinner and thinner. When the smoke diminishes, the temperature may be increased to a considerably higher point than in an ordinary cupellation, in order that the litharge which is formed may melt and pass into the cupel the greater part of the sul-

phate of lead which was formed at the beginning of the operation. The lead now uncovers more and more, and at length appears brilliant. The cupellations may now be finished as usual. This method of assaying tolerably pure galena is quick and accurate. In a series of assays instituted by Malaguti, the ley of silver was sensibly greater by this method than by the crucible operation.

Domeyko recommends the cupellation of the chlorides of silver thus :—Take six grammes of the chloride, and mix it with ten grammes of granulated lead; envelope it in eight grammes of sheet lead, and melt it in a small crucible. By this means not more than ·004 of silver is lost. He adds, however, that it is better to employ litharge and charcoal, to avoid volatilization of the chloride. But, as we have seen, carbonate of soda must be invariably added to these assays, or else a very considerable portion of the silver is lost.

ASSAY OF SILVER BY THE WET METHOD.

This very ingenious method was invented by the Frenchman Gay-Lussac. It is remarkably simple, clean, accurate, and quick in operation.

Cupellation, after all, only gives an approximate result, whereas by this method mathematically exact results are obtained. All complicated processes will be omitted in the following description, as the assay can be quite accurately made with the simplest means.

APPARATUS, &c., REQUIRED.

Pure rock salt.

Pure distilled water, and pure nitric acid.

Pure silver.

Three or four pipettes accurately marked to 1000 grains.

Six or eight decimal pipettes, marked in ten equal divisions = 100 grains in all.

Half-a-dozen glass stoppered bottles, having

the numbers marked both on stopper and shoulder.

Perfectly clean hands, free from perspiration.

METHOD OF ASSAY.

Take 162·5 grains of the pure salt, or a little more. Dry it carefully and thoroughly, and weigh the 162·5 grains accurately before quite cold. Clean out an ammonia bottle, and put the salt in, and add 30,000 grains of the pure distilled water. This constitutes the *normal* solution. Take 1000 grains of the above solution, and run them in another smaller bottle with a wide mouth, and dilute to 10,000 grains by adding 9000 grains of distilled water. This is conveniently done by buying a bottle of 10,000 grains' capacity. This forms the *decimal* solution of salt. Take 10 grains of quite pure silver, most accurately weighed, and dissolve it in a little *pure* dilute nitric acid, and dilute it to 10,000 grains by adding pure distilled water as above described. This forms the *decimal* solution of silver.

First of all, standardize your solution. To do this, take 10 grains of pure silver; dissolve it in pure dilute nitric acid (half water). Blow off the nitrous fumes with a bent glass tube until there are no more of them left: this is effected in one of the stoppered bottles. Now dilute to about a quarter of a pint, and warm the solution till nearly the boiling point. This can be most conveniently done by placing a large saucepan on the fire or brazier, and making the water boil: then immerse the bottle in the water. While the bottle is still in the saucepan, take a pipette full of 1000 grains of the normal solution, and, placing the nose of the pipette in the bottle, let the measure run in. Now replace the stopper, and, taking hold of the bottle with a damp cloth, place your two thumbs on the stopper, and shake violently for at least five minutes. Then give a circular twirl and allow to settle.

Now take the decimal solution of salt, and run in 10 grains of solution at a time, warming and shaking the bottle after each application.

Suppose the first six give a precipitate, and the seventh does not, the seventh and *half* the *sixth* are not counted. Thus:

Normal solution	1000
Decimal solution	7
	1007
Less . . .	1·5
	1005·5

This represents the standard of the normal solution. Now take as much of the alloy to be assayed as will equal 10 grains of pure silver, which must be found out by previous analysis. Dissolve in nitric acid, and run in the normal and standard solutions as before, when, of course, the amount of fineness in the alloy can be easily ascertained by a proportion sum.

OBSERVATIONS ON THE ABOVE METHOD.

Although the above method sounds remarkably easy and simple, and indeed is so, still a variety of precautions are to be taken.

The nitric acid must be quite pure. The distilled water for this operation ought to be especially kept for this purpose : the first water that comes over from the still ought to be used for the ordinary purposes of the laboratory, and the succeeding portion kept in clean earthern jars well stoppered. The pure silver for the solution is better obtained from dissolving a florin in nitric acid, adding pure water, and then precipitating with hydrochloric acid till no more precipitate forms. Dry the precipitate in a porcelain dish over a sand-bath, and run down the residue with a small quantity of carbonate of soda in a clean crucible. If the greatest exactness is required, dissolve the resulting button again; precipitate and melt again, when the silver is perfectly pure.

The best way to arrange the bottle of normal solution of salt is to insert a cork fitted with two glass tubes, one bent in the form of a syphon, and fitted with a long piece of india-rubber tubing reaching nearly down to the bench where you are taking the assays, the bottle having been

previously placed on a shelf a foot or two above. A small point tube, like a burette point, is now fitted to the end, and a pinchcock fastened on about three inches above the point. When you want to take a measure of 1000 grains of the solution, place the thumb of the left hand on the outlet of the pipette, placing the fore and middle finger on the shoulder above, thus securing it tight. Now introduce the point of the syphon connected with the bottle, and (having previously well shaken the solution, and run a little through the pipette to clean it) run in gradually till an inch past the mark on the neck. Let go the pinchcock and remove the point, and place the forefinger of the right hand firmly on the top of the pipette, removing the thumb of the left. Now wipe the pipette with a clean silk handkerchief, and gradually loosen the tightness of the right forefinger, and allow the solution to run down to exactly the mark; immediately introduce the point of the pipette into the assay bottle as far as the shoulder, and let the solution run in. When all the solution has run, lift the pipette

out, without shaking the superfluous drops off. It is much better for the operator to do this than to try and get rid of all the lost drops of the solution, as a well-made pipette will drop precisely the same for any number of times following. The pipettes for the decimal solution are much better when made with the graduations marked the opposite way from that usually pursued, viz., with the ten degrees at the bottom, next the point, and the hundredth division at the top. The reason is that, by immersing the pipette in the decimal solution bottle, you can easily take a measure of a tenth, and let it run out clean into the bottle of alloy, as in the case of the normal solution; whereas in the pipettes marked in the ordinary manner, viz., with the ten degrees at the top and the hundred at the bottom, you have to run out the solution *to* a fixed grade; if you let your finger slip, or have not sufficient practice, you can very easily run past this grade, and spoil your assay. The last drops from this smaller pipette are best blown out into the assay solution with a slight

breath, and not left in the normal pipette. The bottles used for this assay should be well stoppered, and of sufficient size to allow the shoulder of the normal solution pipette to rest there, so as not to waggle about when letting the solution run in. Be careful not to touch the nozzles of the stoppers with your fingers, and always place them, with their ends upwards, on their backs, when removed for the purpose of letting a solution run in. In fact, everything should be touched as little as possible, as the slightest perspiration will cloud the solution, and very often the acid, or the water, or the test silver is denounced as impure, when the fault is in the clumsiness of the assayer. The hands should be well washed with soap and water before commencing this assay, and occasionally wiped on a towel by the operator's side.

After each application of solution the bottle must be violently shaken, and replaced in the hot water in the saucepan. If the clear water on settling has a bluish tinge, like quinine solution, copper is present; but this does not inter-

fere with the estimation of the cloudiness on the application of the decimal solution. When finished with, the bottles must be well washed with distilled water, and the stoppers replaced. It is best to put them away in a drawer free from dust, &c.

Suppose, then, the assayer has three samples to be determined (and unless he is in a mint he is not likely to have more), he will proceed as follows :

Thoroughly clean four bottles, and see that the numbers on the stoppers and shoulders agree; weigh off ten grains of pure silver, and standardize your solution first of all, We will suppose the standard is 1000. If the approximate standards of the alloys are not previously known, they must be found out, either by cupelling or by the above process. If by cupelling, take about three grains, and cupel with about thirty grains of pure test lead. If by the wet method, its approximate value must be guessed as near as possible, and an amount that would more or less equal pure silver be dissolved, and

its standard sought by the solutions. Supposing, however, that their supposed standards are 900, 953, 870: now search in the *salt* columns for the numbers nearest to them. They will be found to be 11.10, 10.50, 11.50 respectively. These weights are to be weighed up most accurately, and carefully dissolved in pure nitric acid, with all the precautions pointed out. Now take a pipette full of the normal solution, and run in each bottle; replace the stoppers, and shake violently; proceed with the decimal solutions: run in each of them a tenth of the salt decimal solution. Suppose a cloudy precipitate falls down from the two first, but *not* from the last one. Agitate the two first ones well, and replace in the saucepan. We know, by no precipitate falling down in the third one, that we have too much salt solution in already, so we run in a tenth of the *silver* solution to equalize the tenth of the salt solution already run in. We are now where we started from, and we know that we have to start with the nitrate solution again. Accordingly, we run in a tenth of the nitrate

solution; it gives a precipitate: another, and the same effect follows; and so on, five times. The sixth, however, does not. Consequently, as before stated, we deduct the sixth and half the fifth, making four and a half run in to be counted. To find out, therefore, the real standard, which was supposed at first to be equivalent to 11.50, we seek in the nitrate of silver columns for the number 11.50, and look out in the fourth column (omitting the half for the time), as we have run in four pipettes of the nitrate solution. We find the number 866.1, which, diminished by ·5, gives 865.6 as the true standard.

Now proceed with the other two. We run in four pipettes of the salt solution: all give a precipitate: the fifth does not. Consequently, we count only three and a half. Now look in the *salt* tables for the numbers 11.10 and 10.50, which represented more or less the required standard of the alloy. We find them 903.6 and 955.2. By adding ·5 to these numbers, we get 904.1 and 955.7 as the required standards.

It saves time and trouble if we endeavour always to avoid having to use the decimal solution of *silver*. We may avoid this by taking particular care to weigh up a sufficient quantity of alloy to equalize pure silver; in other words, to make tolerably sure of having sufficient alloy in our solution for us to commence with the salt solution at once. So much depends on manipulation, that unless a considerable deal of experience has been gained, much handling and equalizing the solutions ought to be avoided.

The salt solution should be kept free from dust or dirt, and occasionally tested.

By means of the above apparatus, which altogether costs only a few shillings, perfectly accurate results are obtained; indeed, much more so than by more expensive apparatus.

The filling of the large pipette with the normal solution may be more effectually and easily performed by means of a filter-stand with two ordinary movable wooden filter rings, thus: screw on the lower one tight, and rest the shoulder of the pipette in it, just sufficiently

high from the table to clear the neck of the solution bottle. Now put on the other ring, and slip it over the tube of the pipette, and screw it on tight down on the upper shoulder of the pipette. Your pipette is now held quite fast. Place the point of the jet connected with the india-rubber tube from the solution bottle in the top of the pipette, and fill as usual. This leaves your hands free to manipulate the flasks, &c.

ESTIMATION OF SILVER BY THE CHLORIDE PROCESS.

There is another method of estimating silver bullion when alloyed with other metals, viz., by calculating the fine metal by means of its chloride.

In November, 1871, an account of it was given by Dr. Busteed, from which the following is condensed :

The samples are accurately weighed as usual, and placed in their respective bottles, and 1½ drachms of nitric acid is added to

them from a graduated pipette, and transferred to a sand-bath, where the contents of the bottles are completely dissolved. The S.G. of the acid in case of alloys is generally 1200; but when the presence of foreign obnoxious metals is suspected, acid of 1320 S.G. is used. Six ounces of cold distilled water are now added, and subsequently $1\frac{1}{2}$ drachms of hydrochloric acid, S.G. 1060. Of course, chloride of silver immediately forms in white curdy clouds of precipitate. The stoppers are then placed in their respective bottles, well washed previously in distilled water, and the bottles and contents are allowed to stand for five minutes. They are then well shaken for three or four minutes, till all the chloride precipitates. Some more distilled water is added till within two inches of the neck, and the contents allowed to stand for four hours. After this, the superfluous liquid is drawn off by a syphon, taking care not to draw up any chloride. More distilled water is added, and, after two hours' rest, is drawn off

as before, and sometimes a third and fourth washing is given. The bottles are then placed on their sides for half an hour, to enable the chloride to settle in one place. Meanwhile a pneumatic trough is prepared and filled with distilled water: corresponding to each bottle there is placed on the floor of the trough a small porcelain saucer with a porcelain cup each numbered correspondingly to the bottles.

The stoppers are then removed from the bottles, and the operator places the forefinger of his hand over the mouth of the bottle, and inverts it over the appropriate cup, and almost down to the bottom. The contained chloride is allowed to fall into the cup by its own weight. If this is neatly manipulated, none of the chloride falls into the saucer. The cups are carefully lifted out and decanted almost dry: they are then gradually dried in a steam bath till the chloride forms a loose cake at the bottom of the cup. They are dried at a temperature of about 300 degrees (F.) for, more or less, two hours, when it is weighed.

If the operation has been skilfully conducted, the chloride exists in a firm, unbroken cake at the bottom of the cup, and can be easily lifted out by a pair of forceps.

The only objection to this process is that if any gold exists in the sample assayed, it is not dissolved, and consequently gets thrown down with the chloride and is weighed and regarded as silver, which accident does not occur by the volumetric method. 18.825 grains of pure silver equal 25 grains of chloride. This weight, therefore, has become the standard weight for an assay. Instead, however, of having to be continually referring to tables, or calculating the proportion of alloy to pure silver, the idea was hit upon of stamping the weights, not with its actual weight, but with the actual value which such an amount of chloride would represent in pure silver. Thus, supposing the resulting chloride weighed 22.5 grains, which would represent 16.94 grains of pure silver, and consequently 900.00 fine, the weight would not have 22.5 marked on it, but

900, so that the assayer simply reads off the value at once.

The whole process takes, more or less, twenty-four hours. Although this process seems peculiarly adapted to the Indian mint, still it is evident that it is a much more tedious process than the volumetric method. Indeed, in the Indian mint it appears that the assays are not reported till the third day. It moreover appears that the gold, as before stated, is estimated as silver, which does not occur in the volumetric analysis. It is also evident that much more apparatus and manipulation is required than in the first process. On the whole, it is difficult to see the advantage of the above method.

BLOWPIPE ASSAY OF SILVER.

This is probably the most useful assay that falls under the practical assayer's notice. Every student who wishes to get a clearer insight into the routine of blowpipe analysis is recommended to obtain Dr. Thompson's

"Guide to Mineral Explorers," Plattner's work on the Blowpipe, and also the Numbers 380–84, 392–98, 412 of the *Chemical News*, containing the observations of David Forbes, F.R.S.

A small portion of the substance to be assayed, varying in size according to the richness of the sample, is to be carefully weighed on the blowpipe balance. This is to be mixed with some granulated lead and soda, and placed in a cavity of a sound piece of charcoal. The blowpipe flame is to be cautiously applied to the substance: after a bit the heat may be increased, and the substance finally fused into a globule of silver-lead, in precisely the same manner as in the crucible assay. It is advisable to take as large a portion as possible of the substance, in order to get more satisfactory results, and invariably to take two or three assays.

The silver-lead thus obtained is then placed on a rather coarse cupel, bound round with a piece of iron wire to hold it by, and the cupel heated in the blowpipe flame, or on the hob

of a fire, to completely dry it. When thoroughly dry, direct the point of a good flame on to the lead, which is forthwith fused, and immediately commences to oxydize and rotate, the same as in a muffle. This oxydizing process must be kept up at the *lowest* temperature that will keep the lead fused, for reasons already explained. The globule must be kept in contact with the melted litharge. If the lead is rich in silver, very little rainbow colours play on the surface. If copper is present in the assay, the cupel will be black; but if the ore is free from foreign metals, the characteristic lemon-yellow of lead appears. When the globule is reduced to about one-third of its size, or the dimension of No. 2 shot, it should be removed from the flame, taking care, as in the muffle assay, not to withdraw the assay too soon, but to cool it off gradually.

A fresh piece of sound charcoal has a hole neatly scooped in the side, and a small quantity of very fine bone-ash, thoroughly dried, is pressed firmly into it with the iron or agate

pestle. It is carefully rounded off and smoothed down, and dried as usual in the blowpipe flame. The globule of silver-lead is then placed on it, and the point of the flame directed on to it for a moment to fuse it; when well fused, draw the cupel away, and keep the point of the flame playing just on the edge of the bead or the bone-ash, but *not touching* the bead, at an angle of 45 degrees. The flame must be hotter than in the preceding operation—hot enough to keep the litharge constantly absorbed, and to prevent it forming under the bead, which would cause the oxydation to stop. If the lead is retarded, as sometimes happens, by minute portions of the cupel or litharge sticking to it, the cupel must be inclined to one side, and the bead allowed to roll down to another place: a small fraction of lead facilitates this. When the brightening takes place, direct the point of the blue flame on the bead for about ten seconds with a good strong blast, to detach any film of lead which might otherwise adhere to it, and cool gradually, to prevent spitting. By this means assays of

silver may be made of the most surprising accuracy.

Should the globule contain much copper, easily recognized by its colour, the bead will frequently come out flattened in shape. When copper is suspected to be in considerable quantities after the first cupellation, some more lead must be added to the globule, and the whole recupelled until the copper is forced off, as in a muffle assay.

Of course the lead used must be quite pure from silver, and finely granulated.

In this class of assay the loss in cupellation is less than in the muffle assay, and is not taken account of by the practical assayer for mercantile purposes; consequently tables for correction are not added. The heat all through the operations should be kept as low as possible. In fact, in all silver assays, except scorification, the heat cannot be too low. Assays of the alloys of silver and copper can be made with equal exactness. The alloy may be submitted at once to the cupel; but Mr. Forbes recom-

mends the addition of borax glass, about half the weight of the assay, and then fusing it on the charcoal in the reducing flame till it begins to rotate, and subsequently cupelling it, as described above. Generally speaking, lead equal to about the weight and a half of the alloy is sufficient, but if copper is present in considerable quantities, it is requisite to add from five to fifteen parts, according to the table given for silver alloys. The resulting button must be re-cupelled if suspected of containing copper; but it is better to avoid this by employing a slight excess of lead, and finishing at once. If the button contains only a small quantity of copper, the assay may be finished at once, without previous concentration.

ASSAY OF GOLD.

THE assay of gold ores is carried on in precisely the same method as that of silver; it presents less difficulty in fact.

It is highly essential that the ores should be thoroughly well ground up and got through an 80 sieve at least. Any flakes of gold that remain in the sieve must be carefully collected and assayed as alloys, and their value added to the amount of the sample, as will be explained. Of course, great care must be taken in getting a fair sample of the packet sent for assay, as, otherwise, rock of a low percentage might easily escape detection.

The furnace, crucibles, &c., are precisely the same as in silver assaying.

In the assay of gold quartz, which will probably be the mineral most presented to the operator's notice, it is usual to take 500 grains as the charge.

The three following mixtures will be found

efficient, according to circumstances and character of the ore :

1.—Gold Ore	.	500
Red Lead	.	500
Charcoal .	.	20
Carbonate	.	600
2.—Gold Ore	.	500
Red Lead	.	500
Borax	. .	150
Carbonate	.	350
Charcoal .	.	20
3.—Gold Ore	.	500
Red Lead	.	1000
Charcoal .	.	20
Carbonate	.	100
Borax	. .	50

The mixture must be intimately mixed in a good sized crucible, with the same precautions as in silver ores. Some assayers recommend a thick covering of salt on the top, but no advantage accrues from this application. Give a good strong heat at the end of the operation,

and pour as usual. The slags in this class of assay are very thick, but they seldom retain any metal: if very viscid, a little more flux added by means of the copper scoop, and a five minutes' brisk heat, will generally render them sufficiently fluid.

All gold ores, unless they are very rich, are much better assayed by this method than by scorification. In the scorification assay of rich gold ores, about ten parts of lead are sufficient, or 50 grains of the ore, and 450 of lead. Unless the sample is very rich, it is better to take four scorifiers, and afterwards scorify the four resulting buttons: the one resulting button can then be cupelled.

The cupellation of gold buttons is very easy. It does not volatilize like silver, and consequently a greater heat can be maintained in the muffle than in the cupellation of silver. At the brightening, if the presence of copper is suspected, a high degree of heat may be safely given, as copper has a very great affinity for gold. The accuracy of the cupellation can be

judged by the appearance of the assay, precisely in the same manner as in silver cupellation.

ALLOYS OF GOLD AND COPPER.

Copper has a remarkable affinity for gold; much more so than for silver. We must, therefore, add a very considerably larger proportion of lead in the former class of assay than in the latter. Generally speaking, this is about double. For instance, in an alloy containing $\frac{900}{1000}$ of gold, about twelve or fifteen times the weight of the whole alloy would be required, and so on. The resulting button does not consist of pure gold, as it always contains a small per-centage of copper. It does no harm to re-cupel the button, as gold is never lost in the operation. In case of re-cupelling, about six times the amount of lead is all that is required. This "surcharge," however, is not reckoned in commercial assays. The presence of silver greatly facilitates the separation of gold from copper; when therefore silver is not

already present in the alloy, a small quantity, say $2\frac{1}{2}$ to 1 of gold, may be added to the assay. In order to find out the approximative value of the alloy, the touchstone may be used, or a preparatory assay taken. The touchstone test, however, is fallacious, unless performed by a very practised operator, and, therefore, no description is needed of the apparatus. It takes very little time to make a preliminary assay, thus: Cupel 5 grains of the alloy with about 100 of pure test lead, and note the result. Then, in the actual assay, add the proper proportion of lead and proceed as usual.

ALLOYS OF GOLD AND SILVER.

The operation of separating gold from silver is called "parting." It is performed as follows:

Take the button which results from the cupellation (in the case of gold and silver ores), and, after correcting for the red lead, note the weight on a delicate balance. This equals amount of gold and silver combined. Now take two and a-half parts, or a trifle less, of pure

test silver, and wrap the gold button and the silver up in a piece of sheet lead. Place a cupel in the muffle, and, when at a good heat, put in about six parts of test lead : when melted, drop in the sheet lead and contents, and cupel as usual. When cool, place the button between two pieces of paper, and flatten it by repeated blows with a hammer on an anvil. Clean it well, and then drop it in a parting flask. Now pour on it three or four spoonfuls of acid solution, composed of one part by measure of pure nitric acid and two and a half of pure distilled water, and allow to boil for fifteen minutes. Carefully decant, and wash once with warm distilled water. Then pour in rather more of an acid composed of half acid and half distilled water, and allow it to boil for twenty minutes, or rather longer. Now decant carefully, as before, and wash the residue with warm distilled water. To get the piece or pieces of gold out of the flask, fill this latter up to the brim, and place a small clay or porcelain crucible on the top, and press it down with the fore-

finger; take hold of the bulb of the flask, and suddenly turn it over topsy-turvy on the table. The gold falls to the bottom of the crucible, and the flask can be lifted out very gently and slowly. If this is effected well, very little water comes out into the crucible. Decant off any water that may be in the crucible, and gently dry off the moisture. When tolerably dry, place the crucible, with the gold in it, in a good hot muffle, and ignite it thoroughly. Now weigh it up, and the difference is the amount of silver in the ore or alloy.

Sometimes the gold button bumps in the flasks. To avoid this, do not use pieces of charcoal, as nitrous acid is thereby generated, unless the charcoal is very pure and well burnt. Use in preference small clay balls of the size of a pea: one in each flask suffices. Suppose the operator has a piece of alloy to assay, quality and contents unknown; proceed as follows:

Weigh off 12 grains on the assay balance most carefully. Cupel this piece with about 300 grains of lead. Mark result; correct for

the lead; the result=fine gold and silver, and the difference some base metal. Say the difference is 3 grains. Note this down in your note-book. Now add two and a quarter parts of pure silver; cupel as described above, with about 200 grains of lead, and the resulting button is flattened out and dissolved as usual. Note the weight, say 6 grains, and the amount of silver is determined. The assay stands thus:

Base metal .	3 grains
Gold . . .	6 ,,
Silver . .	3 ,,
	12 grains

in all; or, as the 12 grains taken represent a troy pound, and as a troy pound contains 12 oz., the report is sent in as follows:

Base metal .	3 oz.	in the	pound troy.
Gold . .	6 ,,	,,	,,
Silver . .	3 ,,	,,	,,
	12 oz.		

Those assays are called "parting" assays

when the amount of fine gold and fine silver is wanted.

Gold bullion can be assayed with different weights, and reported as so many carats, as follows:

Weigh off a quantity of the gold to be estimated, equal to the weight representing 24 carats. Take 25 grains of pure silver, and cupel the whole with about 250 grains of pure lead. Dissolve in the acid solutions as usual, and weigh the resulting gold. Place the 22-carat weight in the balance, and place the gold in the opposite pan of the balance. If the gold is standard, they ought exactly to counterbalance: if it only weighs 21 carats, however, it is "one carat worse;" and if it weighs 23 carats, it is "one carat better."

In parting assays, not more than two and a half parts of silver should be added to the alloyed previous to submitting the quartated button to the acid solutions. If three parts are added, the gold is obtained in the form of a fine powder, much more difficult to weigh up than a

single piece of gold. As a general rule, about two or two and a quarter parts are sufficient for general purposes.

Supposing that, after assaying silver or gold ores, we either get silver poor in gold, or gold rich in silver, or, in other words, where the silver far exceeds the limit of quartation, the button must be flattened out as usual, and dissolved in nitric acid. The gold will remain under the form of a brownish powder, which can be dried immediately, or cupelled with a little lead in a cupel. If the quantity is very small, we can take the powder and dissolve it in aqua regia. Should gold be present, the liquid is tinged a yellow colour; if a drop of solution of chloride of tin is added, a violet hue is produced. Most minute traces of gold can be detected by this means.

The blowpipe assay of gold is conducted in the same manner as that of silver; but as these two metals cannot be separated by any means before the blowpipe, the button obtained must be parted by the wet process as usual.

ASSAY OF TIN.

THIS substance is always met with under the form of oxyde, or in alloys.

The only method of assaying tin ore is by the dry process. Many wet methods by volumetric analysis have been proposed, but as no known acid or acids will dissolve oxyde of tin, they are all fallacious. The oxyde may possibly be dissolved after previous fusion with potash, but this is only a clumsy expedient. All wet methods will therefore be omitted.

First Method.—Grind up the tin ore very carefully in an iron mortar, and get it through an 80 sieve. As this is exceedingly laborious work, it is as well to do it by proxy. After grinding and sieving, mix it up well in the mortar for five or ten minutes, till the powder no longer appears veiny, but homogeneous. Half the discrepancies in tin assays arise from bad sampling. Always take two assays of the same sample.

Take 1000 grains of the well mixed ore;

van it to remove as much silica as possible, and place it in a large blue-pot crucible with 200 grains of anthracite coal, not too fine, about through a 40 sieve. Mix the contents up well, and powder over the top with a layer of anthracite. Place the blue-pot and contents at a strong white heat for twenty minutes in the reducing furnace. Lift the pot out, and scrape down the sides with the charred end of a stick till it is quite clean. Put it in the furnace again, and give it the very strongest heat possible for a quarter of an hour. Lift out the pot, and pour into a mould as quickly as possible.

Allow the pot to cool, and scrape out the residue with a knife into an iron mortar. Wash off as much as possible of the charcoal slags, &c., and run down the remainder in a common Cornish crucible with carbonate of soda. Pour as usual, and add the result to the first ingot. In this operation great care must be taken to grind the ore fine, to have your furnace at a white-heat, and to pour carefully the first time. The best

way to effect this latter operation is to push back the slags, &c., from the molten metal in the crucible with a piece of stick, and to place the mould across the mouth of a large iron mortar, and then pour out as much as possible. All that does not go into the mould drops into the mortar. This method gives fair results ; but its great objection is that it requires such a high heat, which the explorer cannot often obtain.

Second Method.—Take 100 grains of the fine-powdered ore, and 200 grains of coarsely pounded common cyanide of potassium, and mix up in a small Cornish crucible, together with 25 grains of charcoal. Powder over the top with another 50 or 60 grains of potassium, and place the crucible in the reducing furnace for twenty-five minutes, at a low heat—only just sufficient to keep the cyanide fused. Cover over the top with a piece of broken pot. Give a minute's slight increase of heat at the finish, and pour into a mould. The results by this method are exceedingly correct. This method possesses the great advantage of not requiring a higher

heat than an ordinary kitchen fire. Some precautions, however, must be taken when pursuing this method of assaying tin.

The best place to put the crucible is on the top of the furnace, with the top bricks open, much the same as in roasting operations, and the great point is to keep the *top* of the pot as hot as the bottom, so as to let the fused cyanide run down well, and not adhere to the sides. The piece of broken pot is to keep the top of the crucible and the contents as hot as the bottom, by confining the heat as much as possible. The object being to keep the cyanide *in* the pot, and not to volatilize it, if dense white fumes come off, the furnace is too hot, and the crucible must be immediately removed.

Domeyko proposes the following method :

Treat 100 grains of the mineral with aqua regia, and after washing and calcining the residue, it is mixed with 20 grains of charcoal of white sugar, and covered over with 100 grains of the same charcoal. The mixture is placed in a small porcelain crucible for a quarter of an

hour, in a good muffle furnace: the crucible is then taken out, and the residue treated again with aqua regia, and the tin precipitated from the solution by pure zinc.

Domeyko also recommends the use of cyanide of potassium as follows:

Take 200 grains of the ore, and treat it as above described, as far as heating it in a muffle furnace. Then, instead of taking out the crucible and treating the residue with aqua regia, 300 grains of cyanide are introduced into the crucible, and the whole heated for five or ten minutes at a cherry-red heat.

ALLOYS OF TIN.

Iron, tungsten, &c., are usually reduced with the tin, and sometimes it is advisable to ascertain the proportion of these metals. If the ingot is malleable, it is reduced to thin leaves, or if it is brittle it is pounded up as fine as possible in an iron mortar. It is afterwards boiled with pure concentrated muriatic acid until the residue ceases to be attacked. The solution contains

tin and iron. The tin is then precipitated by sulphuretted hydrogen gas. The deposit is collected and treated with nitric acid: it is then evaporated to dryness, and the residue calcined into deutoxyde of tin. The solution or filtrate containing the iron is then boiled with nitric acid, in order to peroxydize the iron, and the peroxyde is precipitated by carbonate of ammonia. The residue of the alloy which has not been dissolved in muriatic acid is tungsten, with only a trace of iron.

When the exact amount of iron, however, is required, the tungsten can be heated with twice its weight of saltpetre in a silver crucible, and afterwards washed with water: the tungsten dissolves, and only pure oxyde of iron is left.

When there is much iron in an alloy, it is less attackable by muriatic acid than when there is a large excess of tin. In this case it is better to fuse the alloy with a known quantity of pure tin, and commence as before. If not, the alloy must be boiled for some hours, during which some tungsten is oxydized, which will give a dark-blue

colour to the solution. If we suspect zinc is alloyed with the tin, it is easy to determine the quantity by dissolving the alloy in pure nitric acid, in which only the zinc is dissolved, while the tin remains in the residue in the state of oxyde. The solution is evaporated to dryness, and the residue calcined at a red heat, to transform the nitrate of zinc into oxyde. When we have an alloy of copper and tin, it must be dissolved in aqua regia, adding water and an excess of ammonia. The precipitate is filtered, and washed with ammonia diluted largely until the filtered water ceases to assume a blue tinge. The solution is boiled to expel the ammonia, and the liquor saturated with muriatic or sulphuric acid, and the copper precipitated by iron in the usual way. The only difficulty which occurs in this case is that in the filtration of the ammoniacal liquor, small white particles of oxyde of tin pass through the filter. But this may be avoided by adding two or three grains of lead to the solution before the addition of the ammonia.

Tin may contain copper, lead, iron, and arsenic. To determine the lead and copper, the piece of tin must be flattened out, and treated with nitric acid at boiling point, until it is completely oxydized. The liquor is evaporated to dryness, filtered, and the residue calcined. If this residue is white, it consists of pure tin; but if iron is present, the residue is tinged more or less yellow. The nitric solutions are evaporated to dryness in rotation, and the residue calcined in a platinum crucible: this residue is again dissolved in pure nitric acid. The lead is precipitated from the solution by sulphuric acid, and afterwards the copper by a plate of iron. To determine the quantity of iron and arsenic, another portion of tin is dissolved in muriatic acid, and the operation proceeded with as before.

When the tin does not contain lead, we can attack it by concentrated muriatic acid, to dissolve the tin and iron; but it is necessary to stop the action of the acid before all the assay piece is dissolved, or otherwise the copper

would be dissolved at the same time. The residue is well washed, and treated with nitric acid, &c. The copper and the iron can thus be determined at one and the same time.

ASSAY OF TIN BY THE BLOWPIPE.

Galin's well-known method, by which the most minute traces of tin can be discovered, is as follows :

A small portion of the mineral is slightly moistened and mixed with anhydrous carbonate of soda : it is then placed in a cavity in a sound piece of charcoal, and exposed to a good hot reducing flame ; some more soda is added, and the flame again applied. As long as any of the substance remains on the charcoal soda is added, until all the mass is absorbed and reduced.

Extinguish the burning charcoal with a drop of water, and cut out the assay piece and surrounding part ; grind it up fine in an agate mortar. Grind and work alternately until all the charcoal, &c., is worked away. If any reducible substance is present, it will be found at the bot-

tom of the water; if it is malleable, it will be in the form of lamina, and if brittle, in the shape of fine powder. By this means may be discovered half per cent. of tin. It must be observed that a good hot flame must be kept up, and all the assay covered by it.

Very accurate results may be obtained as follows:

Mix one part of the mineral with three or four parts of carbonate of soda, and place on the top of it a piece of cyanide of potassium the size of a pea after the mixture has been previously heated. Now apply a good strong reducing heat as before, and a globule of tin will be obtained.

It is necessary for the practical assayer, and more especially for the explorer, to be able to judge of the purity of the tin, whether obtained by assay or by smelting. There are two methods of doing this.

First.—By the noise which the ingot gives when bent, which is louder in proportion to the purity of the metal.

Second.—By the appearance of the ingot when it sets. The tin to be tested must be melted in a crucible at the lowest temperature sufficient to effect it. Take the crucible out of the furnace, and clean off the oxydizing surface with a piece of stick, and wait till the surface presents a peculiar yellowish film. Now pour the tin into a dolomite mould, in a room perfectly quiet, and free from shaking. When it sets, observe the colour and the indications more or less of crystallization. The whiter the metal, and the less signs there are of crystallization, the purer the tin is. A good ingot of tin sets quite smooth, white, and with a slight longitudinal furrow down the centre, like an ingot of copper; but if the tin is impure, the surface is covered here and there with stars and spikes, and these are in greater or less abundance according to the purity or impurity of the metal.

ASSAY OF LEAD.

By far the most general ore of lead that comes under the assayer's notice is galena. Lead ores are always assayed by the dry method. Several wet methods are given in hand-books, but they are all objectionable, and consequently no notice is taken of them. There are two methods of assaying lead ores; first, by using an iron pot; and, secondly, by using an earthern crucible and introducing iron in the assay. The first method is that usually practised and recommended at the School of Mines, and is the best method of assaying lead ores.

These pots must be of the ordinary cylindrical shape, and welded solidly together, not merely brazed. They will last, with care, for fifteen to twenty assays.

The ore must be got through a 60 sieve, and, as in the case of tin ore, carefully mixed up to secure a homogeneous sample, which very often causes great errors.

The following mixture can then be mixed up in a sheet of glazed paper:

Ore . . .	400
Carbonate . .	400
Borax . . .	100
Argol . . .	30

reserving most of the borax, and 100 grains of the carbonate of soda, to cover with. The crucible is heated to just a glow in the furnace, and then the mixture is projected carefully in. The crucible is placed at a *low* heat at first, and gradually raised to an ordinary temperature, and the furnace top is closed. When the flux flows freely and smoothly, give a minute's high heat, and then pour into a warmed mould. The object of the final heating is to cause all the lead to flow to the bottom together; but after this object is attained, the contents must not be poured if the crucible is very hot, but allowed to cool for a few seconds; if poured when very hot, a thin coating of lead attaches itself to the iron crucible. If this occurs, a small quantity of flux must be added,

and the residue poured in again. The slags are detached as usual, and the button weighed. If carefully conducted, less lead is lost in this operation than in any other.

Second method: This is performed in the ordinary clay crucibles, with the addition of fluxes and metallic iron. The same amount of ore, fluxes, &c., are to be taken, the contents covered over, and three pieces of hoop iron, or large nails (hoop iron is best), are pushed down to the bottom of the crucible. The crucible is then submitted to the furnace with all the precautions already described; but in this assay the time required is longer than in the former one, being about twenty-five minutes. Before throwing away the pieces of iron, they must be examined to see if any buttons of lead still adhere to them, and, if so, they must be dipped and washed in the bath of lead till they are all detached. Examine the crucible for shots of lead, if necessary adding a little flux.

In the assay of carbonates the same charge is taken, and iron can be advantageously used.

Indeed, the above No. 1 method can be applied to almost all classes of lead ores.

The following method is the one recommended by Mitchell, and is perhaps as good as any: Grind up 200 grains of the galena, and get it through a 40 sieve. Mix this with 50 grains of argol and 200 grains of carbonate of soda, and place the whole in a crucible which has been well smeared over with common black-lead. Then insert three large nails (hoop iron is much better), and cover over the top with 200 grains of common salt, and over that 200 grains of anhydrous borax. Place them in the furnace, and raise the heat rapidly to a bright red; then take off the cover of the furnace for eight or ten minutes. Cover the furnace up again, and raise the heat again to a bright red: when the flux flows smoothly, pour as usual, after washing the pieces of iron.

The only corrections to be made are *not* to rapidly raise the heat, and not entirely remove the cover of the furnace. Care should be taken also to keep the top of the crucible as hot as

the rest of the contents, by packing the coke around it, as in roasting operations.

By the above method, carefully performed, equally good results may be got as by any other. When galena contains silver or gold, both these metals pass into the lead entirely, and the contents must, of course, be certified for, as, whether the ore is assayed for silver or for lead, the assay, with only some small modifications, is the same. If copper is present, some goes into the lead, and some into the slag. These buttons are harder than pure lead. Antimony renders the buttons brittle and granular; they also are harder and more silvery in their appearance.

Litharge and red-lead may be assayed, of course, by the simple addition of a reducing agent and a little flux. Thus, take

400	grains of	litharge
200	„	argol, or
25	„	charcoal
400	„	carbonate
100	„	borax.

Fuse at the lowest possible temperature, and, after a minute's bright heat, pour as usual. When the red-lead is required to be assayed for silver also, take 1000 grains, and a corresponding amount of flux, &c., and reserve the button for cupellation.

The surest way to obtain proof lead for silver assaying is to decompose the best white-lead obtainable, by means of charcoal.

ASSAY OF IRON.

THE estimation of iron by the dry way has been omitted, as also the complete analysis of iron ores and steel. The assay of iron by the dry way requires a greater heat than is usually at the service of the ordinary explorer, while the practical assayer is rarely called upon for a complete analysis of iron, as this belongs more to the province of the skilled metallurgist. I shall, therefore, only describe as plainly as possible the process known as Dr. Penny's—the bichromate of potash method—which, for accuracy, simplicity, and quickness, leaves nothing to be desired.

METHOD OF ASSAY.

Take from 305 to 307 grains of pure bichromate of potash, and dissolve them in four pints of distilled water, in an ordinary ammonia bottle. This forms the *standard* solution.

Take 10 grains of pure, cleaned, harpsichord wire, and dissolve it in pure dilute hydrochloric acid; or, better still, take three or four pieces of wire at hap-hazard, of about 3, 5, 7, 9 grains each, weighed on a most accurate balance, and dissolve them as before. Next take 3 or 4 grains of red prussiate of potash, and dissolve them in at least half a pint of distilled water. This forms the *test* solution. All else that is required is an ordinary burette, and a white porcelain slab, about six inches square, placed on the operator's right hand.

Take 10 grains of the ore to be assayed, if rich; 20 grains, if poor. Put them into a boiling-flask with a small funnel in the neck, and boil with strong hydrochloric acid till all is quite dissolved.

Now shake up your bottle of *standard* solution, and fill up, as usual, a 1000 grain burette with it. Transfer the solution of the pure wire to a large porcelain dish of, at least, one pint capacity; add water, and, having set your burette at the proper mark, place the dish and

contents under it. Now run in a few divisions of the standard solution, stir up with a glass rod, and occasionally test it as follows: Dip a glass rod into the test solution, and make seven or eight small drops on the porcelain slab with the adhering liquor. [N.B.—The slab must be *perfectly* clean and dry.] Wipe the glass rod again, and now and then take up a drop with it from the porcelain basin, and let it mix with one of the drops of the test solution on the slab. When not the smallest trace of blue colour appears on the union of the two liquids, the assay is finished. Read off the number required to effect this, and that is the standard of your solution, precisely the same as in a copper volumetric assay. Say it is 9·65. Now transfer the contents of the flask containing the dissolved ore into a large pint flask; add distilled water, and then about 30 grains of sulphite of soda in crystals. The solution is gradually and gently heated till it is quite colourless, and then it is well boiled, to expel the sulphurous fumes. When the assay is com-

menced the solution must be *quite* colourless. If oxydization sets in, you must add more sulphite of soda and commence again: if care, however, is taken to manipulate pretty quickly, this accident will not occur.

The solution must now be transferred to a similar porcelain dish as in the case of the pure wire, and the standard solution run in as before described.

If the solution appears of a red or orange colour after you have got it into the basin, add a little hydrochloric acid. Sometimes it appears of a dirty-green colour, in which case also excess of hydrochloric acid must be added.

Read off the number of divisions on your burette required to effect the completion of the assay. Suppose 400 grains were required for the completion of the process, and 9·65 has been found as the standard, then we can calculate the percentage of iron in the ore, precisely the same as in a copper assay, by a simple proportion sum.

At first it is rather difficult to exactly see the last few tints on the porcelain slab; but after a little practice the necessary quick-sightedness is soon gained.

ASSAY OF ZINC.

THE old method was by determining the amount of zinc by difference, or by volatilizing the metal or ore at a high temperature, and calculating the loss. The only process, however, that will be mentioned here is that described in Vol. I. of Percy's "Metallurgy."

When a solution of sulphide of sodium is added to an ammoniacal solution of zinc containing a small quantity of hydrated oxyde of iron, the zinc is thrown down as white sulphide of zinc, and the suspended oxyde of iron subsequently becomes black by the excess of sulphide of sodium which has been used in the operation. If, therefore, we know how much pure zinc is precipitated by a standard solution of sulphide of sodium, we can, of course, easily calculate the amount of zinc in an ore sent for estimation, as in a copper volumetric assay.

The two solutions of sesquichloride of iron

and sulphide of sodium are prepared as follows :

1. Dissolve 50 grains of hæmatite in hydrochloric acid, or 35 grains of harpsichord wire in nitrohydrochloric acid, and dilute to 1 pint with distilled water. 2. Take 1400 grains of crystallized monosulphide of sodium, and dissolve them in 4 pints, or 35,000 grains, of pure distilled water. The solution should be clear and colourless, and if any black precipitate appears it must be filtered or carefully decanted off. It should be kept in glass bottles free from lead. This solution is liable to a slow decomposition, so that it requires to be restandardized about every fourth day. If crystallized sulphide of sodium is difficult to be obtained, take 2000 grains of caustic soda, and dissolve them in 1 pint of distilled water. Pour off half a pint into a beaker, and completely saturate it with sulphuretted hydrogen gas. Then add it to the other half pint, and the standard approximately found; afterwards dilute with water till it is of the proper strength

Standardize your solution by weighing off exactly 10 grains of pure zinc, or by taking pieces ranging from 5 to 10 grains apiece at hap-hazard, andtaking the mean. Note the standard as in a copper assay.

Take 10 grains of the ore if rich, and 50 if poor; put them into a flask, and treat with nitrohydrochloric acid, using a small quantity only. When the ore is completely decomposed, a little water is added: ammonia and carbonate of ammonia in excess are added, and the solution is heated gently for twenty or thirty minutes. It is now to be filtered into a pint flask, and the residue on the filter well washed with ammoniacal water. To the filtrate add 50 grains by measure of the sesquichloride of iron diluted with ammonia. Allow it to get quite cold, and then run in the sulphide of sodium solution, *continually shaking* the flask containing the solution of zinc. When the precipitate assumes a greyish black colour, the assay is finished. Read off the number of divisions on your burette that has been required

to effect this, and the per-centage of the ore is easily calculated.

There is a slight error, owing to the fact that a small quantity of zinc remains in the residue after the digestion in ammonia and carbonate; but this is balanced by the fact that a slight excess of sulphide of sodium solution is used to blacken the oxyde at the end of the operation.

Say we have taken 25 grains of the ore; then we have 1000 grains, or 100 divisions, of standard solution (= 10 grains of pure zinc), and as 25 grains of the ore have required 60 divisions (on a burette marked in 100 divisions); we have the sum as in a copper assay, thus:

100 : 60 : : 10 in 25 grains,
or 24·0 per cent.

The liquid must be continually agitated during the process, or otherwise the sulphide of sodium might come in contact with the oxyde of iron and blacken it before the whole of the

zinc is precipitated. Towards the end of the operation, of course the sodium must be gradually added, when the oxyde changes from a mahogany colour to blackish.

If a great deal of iron is present when the ammonia is added, it is better to decant off carefully the liquor, and then treat the assay again with ammonia as before; then filter again.

Manganese, as in a copper assay, may be partly got rid of by carbonate of ammonia; but a little bromine dropped from a glass rod into the ammoniacal solution will entirely remove it.

Copper can be separated by precipitating it on iron wire, as in a copper assay, after dissolving the ore in sulphuric acid. Nitric acid is now added to peroxydize the iron, and then the assay is gone on with as before.

Before the blowpipe blende gives off a strong, intense light, but is infusible: it is of a waxy appearance.

Carbonate of zinc is also infusible. When

heated on charcoal it turns yellow; on cooling it becomes white.

Silicate of lead is infusible: it gives out a green light.

ASSAY OF MERCURY.

Cinnabar is the ore that nearly always comes under the assayer's notice. Its appearance is well known. Mercurial ores are always estimated by distillation. About 500 grains of the ore is taken and placed in an iron or earthenware retort, and the contents distilled over and collected in a flask kept cool by water. If only a small quantity, as 100 grains, are assayed, the most convenient plan is to use a tube over a bath of hot charcoal of the usual well-known shape. The top of the tube must be kept hot, to prevent any mercury adhering to it. The mercury can be collected in a basin of water, dried, and weighed. Graham, in his "Elements of Chemistry," gives the following method:

"To separate it from its compounds in the metallic state, it may be distilled with quicklime in a tube of glass. Into this tube is introduced, first of all, a column of carbonate of lime about an inch long, then the mixture of the sub-

stance with quicklime, then another layer of quicklime two inches long, and then a plug of asbestos to keep the lime in its place. The open end of the tube is drawn out, and bent at an obtuse angle. The tube is now laid in a combustion furnace, the neck being turned downwards and made to pass into a narrow-mouthed bottle containing water, so as to terminate just above the surface of the water. The tube is gradually heated by laying pieces of hot charcoal round it, beginning at the part near the neck containing the pure quicklime. This portion having been brought to a good red-heat, the fire is carefully extended to the middle part, to decompose the compound and volatilize the mercury : any portion of the compound that volatilizes undecomposed will become decomposed in passing over the red-hot lime at the end. Lastly, the back part of the tube containing the carbonate of limeis heated, so as to evolve carbonic acid gas, and sweep out all the mercury vapour contained in the tube. The quantity of gas thus evolved may

be increased by mixing carbonate of soda with the carbonate of lime. The mercury condenses in the bottle, which must be kept cold. The water is poured off as quickly as possible, and the mercury transferred to a porcelain crucible, dried in blotting paper and weighed."

The *Chemical News* describes the following most elegant method for the assay of mercurial ores, and which furthermore possesses the advantage of being accurate :

If the ore is about	1	per cent.,	take	10	grammes.
" is up to	10	"	"	5	"
" "	30	"	"	2	"
" over	30	"	"	1	gramme.

Mix with half their weight of iron filings, and cover the mixture with rather more than a quarter of an inch of clean iron filings. A porcelain crucible has its edges ground perfectly flat, and a gold cup, about two inches across, and of a deep shape, in weight, more or less, 250 grains, is made to fit the crucible most accurately three-fourths of the way up.

Place the ore in the crucible, and then fit the gold cup on the top, and fill the concavity with water kept cold. The gold cup must have been previously accurately weighed. Heat the crucible for ten minutes or so over a Bunsen's burner or Argand spirit lamp, and the mercury deposits itself on the gold. The gold cup is then removed, and the mercury washed with alcohol from a wash-bottle. After being allowed to cool, and dried, the increase of weight gives the per-centage. The mercury can be removed by gently heating it over a spirit lamp where there is a good draught.

In this assay the cover must fit closely, to avoid loss of mercury by volatilization, and must be deep enough to hold a considerable quantity of water to keep it cool, although small pieces of ice might effect this if at hand. The iron filings must be clean. When assaying rich ores, the alcohol used for washing must be collected, and any minute traces of mercury collected by pouring it into the cup of gold, which will take up any that remains.

Before the blowpipe cinnabar volatilizes, and gives off a smell of sulphur. If a small piece is mixed with a little carbonate of soda, and placed in an iron spoon, and heated over a spirit lamp, the volatilized mercury may be collected on a sovereign or small plate of gold held about half an inch above it. Weigh the plate, and the difference gives the per-centage. This is an exceedingly accurate test for mercury.

If an ore is suspected to contain native mercury, it may be discovered by simply heating the mineral in an iron spoon by itself and collecting on a gold plate as before.

Assays of mercury in a small way may be very conveniently performed as follows :

1. Mix a small quantity of the material with iron filings or metallic tin, and heat the mixture in a close tube to a bright red. The mercury sublimes, and collects in the coldest part of the tube, like a metallic dew. Collect the globules with a perfectly dry feather.

2. A still better method is to take a closed tube of about seven or eight inches long: bend

round the closed end like a small retort: this bent part should be about two inches long. Dry the tube well over a spirit lamp, and introduce 10 grains of the powdered material, with about two parts, or rather less, of litharge. Heat the curved part slowly at first, but gradually increase the heat until the material is fused completely. The water which is formed condenses and goes out at the open extremity of the tube, while the mercury forms like a dew, and sometimes like a barely perceptible cloud, at the point where the tube begins to curve. Then, in order to collect the mercury, the curved part is introduced a little further into the fire, so that the small drops of mercury which are disseminated through the tube may unite nearer the orifice, and form a ring, which ring can be driven as far as convenient from the curved part by means of the hot flame of a spirit lamp. Then cut off the glass near the ring of mercury, and collect the mercury with the dried feathers of a pen: let the drops fall

into a capsule of water, and heat for a moment to unite them into one button, and then weigh.

This method of assay is most exceedingly exact, and is especially adapted to arsenical ores.

The tube must be bent, as otherwise the water which is evolved would be continually flowing back to the bottom, where the tube is hottest, and would consequently break the glass, or, by spitting, cause loss of the material under assay.

3. Place about one grain of the material on a sovereign, and add a drop of muriatic acid: drop in the acid a morsel of tin. If mercury is present, an amalgam is formed immediately on the sovereign. Wash off the acid, tin, &c., and a metallic white spot appears where the tin was.

ASSAY OF MANGANESE.

THE value of the ores of manganese entirely depends on their relative power of evolving chlorine. The amount also of some foreign bodies, notably protoxyde of iron, should also be estimated, as these diminish the value of the ore. Many methods have been proposed for the assay of manganese ore.

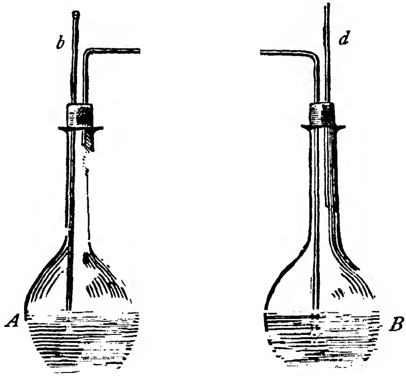


Fig. 1.—Will and Fresenius's apparatus.

1. *Method of Will and Fresenius.*—This well-known method consists in taking 50 grains

of the ore to be examined, and introducing it into the flask *A* of the figure 1, together with 150 grains of neutral oxalate of potash, which may be easily prepared by saturating oxalate of potash with carbonate of potash, and evaporating to crystals. Concentrated sulphuric acid is then poured into flask *B* of the same apparatus till it is about one-third full. Now cork up the two flasks with the connecting rods, and weigh the whole *accurately*. Plug up the opening *b*, and suck up a little air from *d*. A vacuum is caused in *A*, and a little sulphuric acid passes from *B* into *A*. The oxygen which is contained in the manganese will react upon the oxalic acid, which will generate carbonic acid. This carbonic acid passes into the flask *B*, is deprived of its moisture by the sulphuric acid, and escapes out at *d*. The same process must be gone through again and again till no more gas is evolved. Now remove the plug at *b*, and suck at *d* till no more taste of carbonic acid is noticed and the apparatus is filled with common air. Wait till the flasks are quite cold,

and then weigh: the loss of weight represents the amount of pure peroxyde of manganese.

The following was recommended by Dr. Thompson; and, if tolerably carefully performed, gives pretty fair results:

Take 50 grains of the mineral, finely ground, and place them in a small Bohemian glass flask with about $1\frac{1}{2}$ oz. of water and $\frac{1}{4}$ oz. of sulphuric acid. Then in the neck insert a plug of cotton wool, to absorb the moisture of the carbonic acid as it passes out. A tube with dried chloride of calcium may be used if preferred. Now weigh the flask and contents, and immediately afterwards introduce 100 grains of oxalic acid: replace the wool, and let the flask stand for some little time during effervescence. Then apply a *very gentle* heat till no more carbonic acid is evolved: allow the flask to get quite cold, and weigh. The loss of weight corresponds to the amount of peroxyde in the ore. Suppose it loses 30 grains (in 50 grains), then the per-centage is 60 per cent.

The ordinary method for *available* amount of

manganese is that known by the name of Otto's process, which consists in combining the mineral with an iron salt, and then, by means of a bichromate standard solution, estimating the excess of the iron; thus reversing the order of the ordinary iron assay. Any known quantity of pure harpsichord wire is dissolved in pure dilute sulphuric acid (1 of acid to 3 of distilled water): 30 grains is a convenient amount. A flask is fitted up with a bent glass tube, so that the end dips into a small beaker containing a little water. The large flask containing the wire is heated till it is dissolved. Now introduce an equal amount of the ore to be estimated, replace the cork, and boil gently till the soluble part of the manganese is dissolved. The lamp being taken away, the water from the small beaker is allowed to run back into the larger flask. The tube, beaker, &c., are well washed out, and water is added to the larger flask until it is about half full. The excess of iron can now be estimated by a standard solution of bichromate. The difference be-

tween the amount indicated by the standard solution and the original amount taken, viz., 30 grains, gives, of course, the amount of iron that has been peroxydized by the manganese, and from these *data* can be calculated the amount of peroxyde of manganese. For instance, supposing 30 grains originally taken. Then we have, say :

5	grains	of iron	unoxydized
30	,,	,,	originally taken
25	,,	,,	remain oxydized.

Now, 25 grains of iron are equal to 19·23 grains of peroxyde of manganese: as we took 30 grains, we get, as the percentage, 64·10 of peroxyde in the ore.

Any iron that passes over is arrested by the water, and, of course, is washed back into the larger flask. The standard solution is prepared in precisely the same manner as recommended under "Iron Assay," viz., 1000 grains of bichromate = 10 grains of iron.

If the ore contains more than 75 per cent. of

peroxyde, either less ore or more pure iron must be used.

Graham also gives the following method of readily estimating the value of the bioxyde.

Fig. 2.—Graham's method for estimation of manganese.

Take a small flask of about 4 oz. capacity, fitted with a perforated cork. A tube, about 3 inches long, is drawn out at one end, and filled with pulverized chloride of calcium, to absorb moisture: it is passed through the perforated cork, and a small, short test-tube, small enough to go *inside* the flask, is filled with 100 grains of hydrochloric acid. Fifty grains of the finely powdered mineral are placed in the flask, together with about half an ounce of cold water. The tube with the acid is now intro-

duced, and also 50 grains of crystallized oxalic acid. The chloride of calcium tube is fitted on, and the whole apparatus weighed *directly*. The flask is then inclined, so as to allow the acid to flow out of the tube and come into contact with the oxalic acid and manganese: a gentle heat is at the same time applied. Carbonic acid is evolved, and escapes through the calcium tube. To expel all the carbonic acid, the solution must be gradually heated to boiling point, after which it is allowed to get quite cool, and then weighed. The loss of weight gives the quantity of carbonic acid. Now, as 43·67, the equivalent of bioxyde of manganese, is nearly double that of carbonic acid, which is 22, the loss of weight in the apparatus may be taken as equal to the quantity of real bioxyde in the 50 grains of the sample.

This process, though not peculiarly exact, gives tolerably good results for approximate assays, and can be performed with the simplest apparatus, in a minute or two.

ASSAY OF BISMUTH.

This metal, which is becoming of such value, is well worthy of the assayer's and explorer's notice, if he is lucky enough to come across any deposits of it. Native bismuth, the sulphurets, oxydes, and carbonates can be assayed by an ordinary flux and reducing agent. Thus, take:

Ore	100
Carbonate	250
Argol or charcoal as usual.	

Or,

Carbonate	200
Borax	100
Argol, or cyanide of potass .	100

Mix and cover in a crucible, and fuse with the ordinary precautions. As, however, bismuth is most exceedingly volatile, this must be effected at as low a temperature as possible.

When, however, there is a great quantity of copper in the ore, the copper is reduced with

the bismuth, and must be separated. The ores of Bolivia and Northern Chile nearly always contain copper.

Mr. Hugo Tamm, in No. 640 of the *Chemical News*, has given the following method for purifying bismuth from copper, arsenic, antimony, and sulphur.

1. *Copper.*

Eight parts of cyanide of potassium and three parts of flowers of sulphur are mixed together, and one part of this mixture is sprinkled over sixteen parts of the molten metal, at the lowest possible temperature.

A reaction takes place, and the metal is brought to a red heat, and the sulpho-cyanide begins to burn vividly, throwing out blue scintillating sparks.

The crucible is covered over, and great care must be taken not to let the heat get higher than the burning point of the sulpho-cyanide, because sulphuret of bismuth would commence to volatilize.

After the contents of the crucible have

settled and been well stirred with a clay stirrer, the metal is poured into a mould after the flux has set.

2. *Antimony.*

Calculate more or less the amount of antimony there is in the alloy, and add about three times the amount of oxyde of bismuth. The oxyde of bismuth is instantaneously reduced to the metallic state, and oxyde of antimony formed, which floats on the top, and can be easily removed. Of course, iron and carbon must be carefully excluded in this operation.

3. *Arsenic and Sulphur* are easily removed by melting the metal under cover of a flux to prevent its volatilizing, and strips of iron are plunged into the molten metal. When no more iron is attacked, the crucible is lifted out and allowed to cool. The arseniuret of iron sets, and the molten bismuth underneath is then poured out into a mould.

Pure bismuth fractures bright, and with a reddish colour. When arsenic is present, the fracture is more silvery, and presents the

appearance of fish-scales. Antimony forms minute crystals: sulphur imparts a blackish tinge.

Antimony may be also detected by dissolving some of the metal in nitric acid. If a cloudy white precipitate forms, antimony is present; but if a crystalline precipitate falls down, which dissolves in water, lead is present.

Arsenic can be detected by heating a piece on charcoal in the oxydizing point of the blow-pipe flame.

When bismuth ores contain a *large* amount of copper, whether in the shape of oxyde or pyrites, the complete separation of the two metals is most difficult. Mr. Tamm recommends his sulpho-carbon process, which depends on the fact that in the presence of alkaline fluxes sulphuret of bismuth is reduced, but not sulphuret of copper.

When sulphuretted ores are under treatment, both the bismuth and copper being in the state of sulphurets, all we have to do is to run them down with some carbonate and salt,

with a little sulphur and carbon, to insure complete sulphurization of the copper.

In case of the oxydes being assayed, we must employ more sulphur, as follows :

Make up a flux composed of

Carbonate soda . . .	5 parts
Salt	2 „
Sulphur	2 „
Charcoal	1 „

and mix it with three parts of the ore. Iron stirrers must be avoided in this assay. When only a small quantity of copper exists in the ore, it is better to run it down with an ordinary flux, and purify the resulting metal afterwards as before described. Mr. Tamm says that in the sulpho-carbon process a loss of 8 per cent. of bismuth occurs, which, he adds, is unavoidable.

Another method is as follows :

Take 100 grains of ore, and treat with strong nitric acid, till the whole is dissolved : evaporate the contents to dryness, and add some

sulphuric acid: evaporate again to dryness, and then add a little acidulated water. Filter, and add carbonate of ammonia in excess. Filter, wash, and dry the precipitate: ignite it in a porcelain crucible, and weigh: every 100 parts = 90 of bismuth (nearly).

To this Graham adds, that if hydrochloric acid is present in the solution, the bismuth cannot be estimated by carbonate of ammonia directly, as oxy-chloric of bismuth would be thrown down with the precipitate. The bismuth must be precipitated by hydrosulphuric acid, the sulphide of bismuth oxydized and dissolved by nitric acid, and then treated as before by carbonate of ammonia.

Mr. W. Pearson has given the following process for assaying bismuth by volume:

Dissolve ·7135 grains of pure crystallized bichromate of potash in 100 grains of water. Prepare two more solutions, one a tenth part of the strength, and the other a hundredth part of the strength of the above, or, to put it in figures, ·07135 and ·007135 respectively. Of

course the quantities can be made larger if necessary.

100 grains of the solution first described (·7135) equals 1 grain of bismuth, and, consequently, 100 grains of the second and third equal ·1 of a grain and ·01 of a grain respectively.

The calculation is evident.

ASSAY OF NICKEL AND COBALT.

THIS is one of the most useful, but, unfortunately, one of the most difficult assays that come under the assayer's notice. The recent discoveries of cobalt ores in South America and the Cape have rendered it necessary, however, that the explorer and practical assayer should know, at least, how to estimate the two together, if not able to accurately determine their respective values. The great difficulty consists in the separation of the nickel from the cobalt.

The method known as Rose's method, given in the "Handbuch der Analyt. Chemie" (Berlin, 1851), is as follows: It principally depends on the fact that protoxyde of cobalt in a solution is converted by chlorine into sesquioxyde; but in the case of nickel this change does not take place. The oxydes are dissolved in hydrochloric acid, and the solution diluted with a large quantity of water—about 1 lb. of water to every 20 grains of the oxydes.

Chlorine gas is then passed through the solution, until in great excess. This must be continued for some hours. Carbonate of baryta is then added in excess, and the whole left to stand for fifteen or eighteen hours, and occasionally shaken up. The precipitate, consisting of sesquioxyde of cobalt and carbonate of baryta, is collected on a filter and washed with cold water. The filtered liquor, which has a green colour, contains all the nickel without any cobalt. The precipitate is then boiled with hydrochloric acid, to convert the sesquioxyde into protoxyde. The baryta is then precipitated by sulphuric acid, and subsequently the cobalt from the filtrate by potash. The nickel from the previous solution must now be precipitated, also by potash, the baryta being removed by sulphuric acid.

The great point is to give a very large excess of chlorine, and also to take care that all the sesquioxyde of cobalt is precipitated by the baryta. The liquor should not be filtered for at least eighteen hours.

Domeyko recommends the following mode of separating these metals, which is the method of Forbes, slightly altered. Domeyko says that he has found it by far the most convenient and accurate of all the methods that he has tried, but he adds that he always begins by running down the mineral to be assayed first of all into a regulus, and then proceeding in the same manner as if the regulus was raw ore :

1. Fifty grammes of the mineral are mixed with 30 grammes of glass of borax and 3 grammes of charcoal. This mixture is introduced into a crucible, and covered over with dried salt, and run down. All the nickel, cobalt, copper, and iron, will be found at the bottom with the arsenic, and the slag is free from nickel and cobalt.

2. Having determined the weight of the button, 1½ grammes of the matter are taken, and calcined in a capsule in a muffle at a red heat. A Bunsen's burner serves the same purpose. Charcoal is added, and the heat kept up until the arsenic is dispelled. The residue is taken

and mixed with 5 grammes of carbonate of soda and 4·5 grammes of nitrate of potash, and run down in a silver crucible.

3. The mass is boiled in water, and the insoluble parts collected on a filter, which is washed with boiling water. This must now be dissolved in hydrochloric acid, adding a little nitric acid, and to the liquor thus obtained carbonate of baryta is added. The solution is allowed to stand some time, and is not heated, but only shaken occasionally. The precipitate is hydrate of peroxyde of iron.

4. Filter the liquor, and add sulphuric acid to precipitate the excess of baryta, and soon after pass a current of sulphuretted hydrogen gas through the solution, by which the copper, lead, antimony, bismuth, and any remains of arsenic are precipitated in the form of sulphs.

5. Having separated these by filtering, the liquor must be neutralized by ammonia, by which the sulphs of cobalt, nickel, and manganese are precipitated. A little time after, before the solution is filtered, acetic acid is added

until the solution acquires an acid reaction. This acid attacks only the sulphs of manganese, without touching the other two, which are collected on a filter, and washed with sulphuretted hydrogen water.

6. Detach these sulphs from the filter, and dissolve them in muriatic acid, with which a few drops of nitric acid have been mixed. From this solution we precipitate the oxydes of cobalt and nickel by caustic potash, or, better still, by caustic soda, adding as little as possible of these reagents. The precipitate thus formed must be well boiled, and carefully washed by decantation, and finally collected on a filter. The washing must be continued till a drop of the water gives not the smallest sign of alcali when evaporated on a slip of glass.

7. If the resulting material was composed only of oxyde of cobalt or of oxyde of nickel, which very rarely happens, we should only have to calcine the residue at a very high temperature, and calculate the cobalt or nickel by the weight of the protoxyde which is obtained. In

case of greater exactness being required, it would be necessary to reduce the oxyde by hydrogen and weigh the metal.

8. If we wish to separate the two, we must first dissolve the calcined oxydes in nitric acid. A small residue of silex may be observed, and must be allowed for. The two oxydes are now to be precipitated by potash, collected in a filter, and washed with boiling water. A solution of pure cyanide of potassium must then be passed through the substance in the filter, and the liquor that passes through collected separately in a flask. The filter is washed with boiling water, until nothing remains in the filter, and the solution boiled. As soon as it commences to boil, oxyde of mercury in very fine powder is introduced (especially prepared by levigation), without stopping the boiling. The precipitate which is formed, besides the excess of oxyde of mercury, contains all the nickel, while the cobalt remains dissolved. The solution is then filtered, the precipitate washed with hot water, and, after drying, calcined at a

red heat. The oxyde and cyanide of mercury go off, and oxyde of nickel remains. The result is weighed, and the difference gives the amount of cobalt.

The cyanide of potassium must be pure, and if this is not the case, it must be calcined with the addition of a little charcoal, and afterwards dissolved in water.

The two following methods for the assay of these metals are the ones best suited to the requirements of the explorer and practical assayer.

First Method:

Take 50 grains of the ore finely pounded and passed through an 80-mesh sieve, and calcine the ore in a clay crucible till it is quite "sweet" and free from sulphur. Not a trace of this substance must be left in the ore. The calcined residue must now be mixed with an equal weight of metallic arsenic, and heated in a small French crucible for about ten or twelve minutes at a not very strong heat. A small round piece of clay is inserted half-way down

the tapering crucible to prevent the rapid disengagement of arsenical vapours. Detach the residue, and place it in a larger French crucible, and add the following mixture:

Carbonate soda	. . .	150 grains
Borax	. . . .	50 „
Tartar	. . . .	50 „

Fuse the mixture at a low heat, and pour out as usual. Weigh the resulting speiss. If iron is not present in the ore, 5 grains or so of fine iron wire MUST be added, as an indispensable condition.

Second Method:

Pass the ore through an 80 sieve. Take 100 grains and dissolve them in nitro-hydrochloric acid. Dilute the solution with distilled water, and filter. Sulphuretted hydrogen gas must now be passed through the liquid (Fig. 1) until in great excess. Filter the liquid, using the sulphuretted hydrogen water to wash the precipitate. Boil the filtrate, and peroxydize the solution with nitric acid. If the filtrate is not peroxydized, a drop of nitric acid will produce

a dark colour; but this colour appears only instantaneously, and must be closely watched.

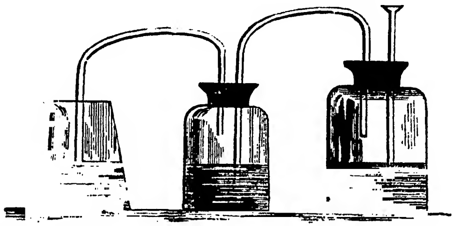


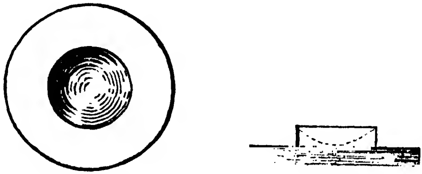
Fig. 1.—Apparatus for making and washing sulphuretted hydrogen gas.

Now add carbonate of baryta till the solution is alkaline; boil the solution, filter and wash the precipitate. Dry the residue, and ignite in a crucible. This residue must now be fused into a speiss with its own weight of arsenic, as in the first operation.

The speiss, however obtained, is to be weighed. If the button is not much larger than a good-sized pea, the whole may be taken for the next operation; but if it is much larger, it had better be broken up and a weighed quantity taken.

During all this time the smallest and strongest muffle that the operator can procure must have

been urged to its utmost heat. The back of the muffle must be difficult to see, on account of the high temperature. A quantity of little clay



Front view. Side view.
Fig. 2.—Clay cups.

cups (Fig. 2) are taken, and two or three placed in the muffle to heat. A dish of coarsely pounded glass of borax is placed on a convenient table, and a washing-basin full of cold water on a stool by the side of the muffle. The operator proceeds as follows:

Remove the door of the muffle, and place a little borax glass in one of the cups, and push it back to the far end of the muffle, and shut the door again. When the clay and borax are at the same heat as the furnace, wrap up the weighed piece of speiss in a piece of paper, and with the tongs drop it into the melted borax. The furnace should be hot enough to instantly

melt the button, this being one of the indispensable conditions of the assay. There must only be sufficient borax to allow the melted button to revolve in, and not enough to *drown* the button. The button immediately begins to rotate, like a silver-lead bead in a cupel, and after a few moments it must be seized with the tongs and drawn quickly out, and plunged, bead and all, as quickly as possible into the basin of water. When cold, examine the borax, and if iron is still coming off, only the characteristic tinge of iron will be observed; but if the very smallest trace of cobalt has come off, the borax will be tinged blue. Directly this occurs, the operator knows that only cobalt, nickel, and perhaps copper, remain. Supposing that no blue tinge appears in the borax, a fresh little cup is placed at the back of the muffle, the button again dropped in and cooled as before, until the blue tinge appears. The operation is proceeded with till all the iron is gone, when the button is taken and placed in a small crucible and covered over with charcoal; it is

melted till no more arsenic fumes are given off, and is then treated exactly as before, occasionally testing the button to see when the cobalt is exhausted. When this point is gained, the button will stop revolving for a time, and the operator must be on the watch for this sign. The cup is now drawn out again, cooled, and the borax examined for the characteristic reddish-brown colour of nickel. Any copper which may be present will come off last.

If carefully conducted, this process is by far the best for commercial purposes, and gives most exact results. The requisite heat is the only difficulty, but by adding some extra iron piping to the chimney of a Plumbago Crucible Company's muffle furnace, placing some anthracite at the bottom of the fire, and carefully choosing the coke, a very high temperature may be got, as long as the muffle itself is a small one. The moulds can be turned for a few shillings.

The estimation of the metals by this process is effected as follows:

Product, after the removal of the iron and

excess of arsenic = $Ni^4 As + Co^4 As$, in varying proportions. Remove the $Co^4 As$, and $Ni^4 As$ is left. But when the weight of each is known, it is easy to calculate the relative amounts of nickel and cobalt. For instance, suppose the weight of the speiss of $Ni^4 As = Co^4 = 20$ grs., and the weight of the $Ni^4 As$, *after* the removal of the $Co^4 As = 10$. The amount of $Co^4 As$ = 10 grains by difference. Then

$$\frac{Ni^4 As}{193} : 10 \text{ grs.} :: \frac{Ni}{118} : x$$

Answer = amount of nickel in weight of speiss ($Ni^4 As$) which has been found from a grain weight of ore.

$$\frac{Co^4 As}{193} : 10 \text{ grs.} :: \frac{Co}{118} : x$$

Answer = amount of *metallic* cobalt in weight of speiss ($Co^4 As$) which has been found in given weight of ore. As, however, cobalt is usually returned as *protoxide*, then we have—

$$\frac{Co}{29{\cdot}5} : \frac{Co}{\text{found}} :: \frac{CoO}{37{\cdot}5} : x$$

Answer = weight of protoxyde of cobalt.

Domeyko recommends the following method for the assay of nickel and cobalt, as most likely to meet the requirements of the explorer and commercial assayer:

Take 5 grammes of the mineral if it is rich, and 10 if it is poor. If its base effervesces with acids and the mineral is grey cobalt, white cobalt, grey nickel, or kupfernickel, without much red or green colour about it, it must first be boiled with acetic acid,

Run down the residue with two or three times its weight of saltpetre, and two or three parts of carbonate of soda in a silver crucible. After the crucible has cooled, it is placed in a large porcelain dish, and boiling water is added, and the whole allowed to stand until the material is well detached from the crucible. The solution is filtered, and the residue washed with boiling water. This residue will contain all the iron, nickel, and cobalt. The filter is dried, and the material detached from the filter; this latter is now carefully burnt, and the ashes added to the material already detached. This precipitate is

now boiled with muriatic acid, and the solution carefully evaporated to dryness. Add water, and filter. To the filtered liquor add powdered carbonate of baryta, taking care not to heat the liquor; add the reagent until iron ceases to be precipitated, and the carbonate dissolved.

Having separated insolubles by filtration, and well washed them with cold water, nothing remains in the solution but nickel and cobalt with the baryta, from which they are easily separated by means of sulphuric acid.

Lastly, the oxydes of nickel and cobalt are precipitated by excess of caustic potash, heating the liquor to boiling point, and washing the precipitate with boiling water. The residue is calcined in a platinum crucible at a red heat.

Domeyko says that, although quite accurate results are not obtained by this process, still it is sufficient for most practical purposes. Cobalt is usually estimated commercially as oxyde, and nickel as metal. 100 parts of oxyde of nickel equal 78·7 parts of metal. The assayer, however, before sending in the result of the

assay, must make a careful examination of these calcined oxydes, after having weighed them. The residue ought to be black oxyde of cobalt with a little nickel, if the ore is a cobalt one; but of a dark green colour (generally speaking with one or two per cent. of cobalt) if the ore is nickel. To examine this residue, we first of all dissolve half a gramme in hydrochloric acid, and add water. Sulphuretted hydrogen is then passed through the solution, to see if it contains copper. If a precipitate is formed, it is collected on a small filter, calcined, and estimated as oxyde. Its weight must be deducted from the result. If any arsenic is present, a yellow precipitate will be formed.

Another half gramme of the calcined oxydes is taken and dissolved in muriatic acid, and the liquor boiled. Water is added, and excess of ammonia, to see if iron and alumina are present. In case of an insoluble precipitate forming, the ammoniacal liquor is filtered, and the residue washed, dried, and calcined. Its weight must also be deducted from the result

This will generally suffice for the practical assayer, particularly when the ore contains little or no nickel; when, however, this latter is in considerable abundance, it becomes necessary to part the two. The following, though not analytically exact, will be found tolerably correct, enough for commercial purposes generally:

Take 1 gramme of the oxydes, and boil them in hydrochloric acid; add a little sal ammoniac, and saturate the liquor with ammonia. If a little oxyde of cobalt is undissolved, add more acid, and ammonia in excess, until the residue remains clear without any residue. This solution is immediately poured into a flask with a ground stopper, and about half a litre of distilled water is added, which has been previously well boiled. A solution of caustic potash is added and the flask closed immediately. Oxyde of nickel is precipitated, and oxyde of cobalt remains suspended in the solution. The liquor, when it has lost all its blue colour, and remains red-coloured, is drawn off by a syphon, and the oxyde of nickel well washed by boiling

water and estimated as usual. The difference gives the cobalt.

It should be remembered that, as the sale of cobalt and nickel ores is in the hands of a very few people who have their own assayers to go by, the every-day assayer will not require perfectly accurate results, but only sufficiently accurate to enable himself or his employers to form a good estimate of the value of the property or ores. Even among professed cobalt assayers, differences of from 5 to 10 per cent. are by no means uncommon.

The sulphate of copper that is deposited by the sulphuretted hydrogen must be calcined in contact with air in a small crucible, and afterwards heated strongly in a platinum one, and then estimated.

M. Terreil, in a communication to the "Bull. de la Soc. Chimique de Paris," 1866, has given the following excellent method for the separation of these metals:

To the solution of the metals, ammonia is added in excess. A solution of permanganate

of potash is also to be added in excess to the hot liquid: this point will be ascertained by the violet colour remaining for some little time. The whole is then to be heated to boiling, and then clorhydric acid added to dissolve the manganese. The liquor is then to be gently warmed for about 20 minutes, and put aside for 24 hours. All the cobalt will be found deposited in the form of a reddish violet powder, which is to be collected on a filter and washed with dilute clorhydric acid, and then with alcohol. It can then be dried and weighed. (110° C.)

The filtrate containing the nickel is boiled to expel alcohol, saturated with ammonia, and permanganate of potash added. The solution is now boiled, when all the manganese precipitates, leaving only the nickel in solution. The nickel can now be separated in the form of sulphide, and changed afterwards into oxyde.

100 parts of the above violet powder equal 22·8 of metallic cobalt, or 29·0 of oxyde.

Before the blow-pipe, cobalt affords the

characteristic blue colour, giving off arsenical fumes.

Arsenical nickel melts on charcoal, sending off white arsenical fumes. In the oxydizing flame with borax bead, it gives a violet colour while hot, and brown-red when cold. Dull grey colour in the reducing point.

It may be added, as a conclusion to the above different methods of assay, that none of them are trustworthy, *as a rule*, except the half-dry and half-wet process, described at pp. 161 and following.

ASSAY OF SULPHUR.

TAKE 100 grains of the ore to be examined, and act upon it by doses of nitric acid, precisely as described under copper assay, till the sulphur is quite clean and yellow. When this point is attained, add hydrochloric acid, filter the solution, wash, dry, and weigh the residue. Now ignite it in a small porcelain crucible, and the loss of weight will be sulphur (nearly). To the filtrate add chloride of barium in excess, and set the flask by for about two hours at a very gentle heat, Collect the precipitate carefully in a filter, wash and ignite it as before; every 116 parts of this sulphate of baryta corresponds to 16 parts of sulphur. Calculate the amount, and add it to the previous amount found by ignition, and the two combined give the amount of sulphur. If the precipitate appears of a dirty yellow or brown colour, owing to iron mechanically carried down, wash the precipitate before filtering with hot dilute

hydrochloric acid. This method is tolerably correct for the estimation say of the amount of sulphur in a regulus for copper smelting. The sulphate, however, is slightly soluble in moderately diluted hydrochloric acid. It is a good plan to heat the filtrate, which should measure about 10 ounces, to about 180 degrees F. If the solution, before precipitation, appears of a reddish colour, add a little hydrochloric acid. Let the precipitated flasks stand about eight hours before filtering. Wash *repeatedly* with boiling water and hydrochloric acid. Mr. Pearson says: "To remove any nitrate of baryta which may be thrown down with the sulphate, wash the precipitate with dilute acetate of ammonia. An equal quantity of tartaric acid, added to the filtrate from insolubles, prevents the precipitation of iron compounds with the sulphate."

ASSAY FOR ARSENIC.

Take 100 grains of the ore and digest it in strong nitric acid till all action ceases, and the ore is quite decomposed. The action of the nitric acid, both in this and other assays, is very much facilitated by the addition of a crystal or two of chlorate of potash. Dilute with water, and filter the solution. To the filtrate add nitrate of lead; arseniate and sulphate of lead are thrown down; collect on a filter; wash, and digest with weak nitric acid, which dissolves the arseniate, but does not attack the sulphate. Filter the solution, and treat with soda in excess, which precipitates the arseniate; collect, wash, dry, and weigh. Every 100 parts = 22·2 of metallic arsenic, or 29 of common white arsenic of the shops.

ASSAY OF NITRATE OF SODA.

ASSAY FOR MOISTURE.

WEIGH out any portion of your sample, say 100 or 200 grains, and dry it carefully in a water bath, until it ceases to lose weight. The difference, of course, gives the moisture. The sample should be gradually dried for about three hours.

ASSAY FOR SALT.

The salt is determined by a standard solution of silver, made as follows:

Take 1 part of nitrate of silver, and dissolve it in 30 parts of pure distilled water or perhaps a little less. Now take 1 decigramme of pure salt and dissolve it in distilled water; run in your standard solution of silver, and note how many divisions on your burette are required to neutralize the chloride, and, consequently, note the standard: say it requires 20 C. C.

Take 5 grammes of the sample and dis-

solve in distilled water; add a few drops of chromate of potash as a detector. Run in your standard solution of silver, as in a copper assay, until a permanent orange tinge is imparted to the solution after stirring, which shows that all the existing chlorides have been neutralized. Now read off the number of divisions, or C. C., required for this purpose, and, of course, the calculation is easy: thus, say it requires 15. Then

$$20 : 15 :: 1 : \cdot 75 \times 2 = 1 \cdot 5$$

of salt in 100 decigrammes of nitrate, or 1·5 per cent.

ASSAY FOR INSOLUBLES.

Weigh out a quantity of your sample, and dissolve it in distilled water. Filter the liquid, wash, and afterwards ignite the filter: weigh the residue, and the difference gives the insolubles. The filter must be well and carefully washed.

ASSAY FOR SULPHATES.

Take the filtrate from the preceding operation, and add chloride of barium in excess;

boil the solution, adding a few drops of hydrochloric acid; filter the solution, and wash the filter thoroughly. Ignite the filter and weigh. The result is found by the following proportion:

	Sulphate of Barium.			Sulphate of Soda.			Quantity found.		Answer.
As	117·5	is	to	71	so	is	x	to	y.

ASSAY OF GUANO.

Moisture is determined in the usual manner, by drying in a water-bath, but it is exceedingly troublesome, owing to the disengagement of ammonia. Mr. Way states that if the substance is treated in a shallow platinum dish with the addition of a few drops of hydrochloric acid, it may be dried at 212 degrees F. without loss. It is better, however, to make a combustion for nitrogen after the guano is dried; if the amount of nitrogen found before drying is subtracted from the total nitrogen found in the fresh guano, and the difference between the two calculated as $2\ (NH_4)_2O,\ 3CO_2$, we have the amount lost in the water-bath: now deduct this from the *actual* loss, and the true moisture is found.

Organic matter is found by taking 50 grains and burning off in a platinum crucible till nothing but ash is left. The ash of good guano ought

to be a perfect white. The heat should not be too high.

Sand is found by taking the above and treating it with hydrochloric acid and water; when nothing more is dissolved, wash, dry, ignite, and weigh.

Phosphates.—These are estimated by taking the filtrate and washings from the sand, slightly diluting it with water, and adding an excess of ammonia. The precipitated phosphates are collected on a filter, ignited, and weighed.

The value of guano almost entirely depends on the quantity of nitrogen it contains, so that the estimation of this is worth all the rest put together.

Estimation of Nitrogen.—Most nitrogenized bodies, when heated with soda-lime, give off the whole of their nitrogen in the form of ammonia. This soda-lime is prepared by adding powdered quicklime to soda-lye of known strength, so that there are two parts of quicklime and one part of hydrate of sodium. The mixture must be evaporated to dryness in an iron pot, cal-

cined in a crucible, finally ground fine in a porcelain crucible, and kept in a close-stoppered bottle. If commercial soda is used, take care that no nitric acid is present.

Weigh out the substance to be analysed (guano), and add to it, in a warm porcelain mortar, a quantity of the soda-lime, making up enough to about, or nearly, fill a common combustion tube two-thirds full. Now clean out the porcelain mortar with fresh soda-lime; add this on top of the mixture already in the tube, and over all put a little fresh soda-lime; insert a plug of recently-ignited asbestos, and the tube is ready. Substances like guano ought to be mixed quickly to prevent loss of NH_3. Church recommends that the mixture should be effected in the tube itself by means of a cork-screw shaped wire, taking care to leave an inch of pure soda-lime at the end. Give the tube a few gentle taps on the bench to allow a passage for the gas, and attach the ordinary nitrogen-bulbs or U tubes, containing 20 C. C. of dilute standard sulphuric acid. The bulbs are filled by

suction, and the whole apparatus must be quite air-tight. First heat the front of the combustion tube containing the pure soda-lime; then, when this is red-hot, heat the mixture, keeping the front red-hot all the time, and soon gradually to the closed end. Finally, nip off the end of the tube, and draw air through the tube in the usual way. The acid contents of the bulbs are emptied into a beaker, some solution of litmus added, and the quantity of free acid remaining estimated by a standard alkaline solution. From the amount of alkaline solution required to effect this the percentage of ammonia may be readily ascertained.

The litmus solution is prepared by digesting powdered litmus in twenty times its weight of distilled water for eight or ten hours, and then decanting it. Pour off half, and add a little very dilute nitric acid; now mix the two together, and the whole will be *violet*, not red or blue. It should *not* be tightly corked.

Fresenius's method of making standard acid and standard solutions is as follows:

Standard Acid.—Take 100 C. C. of strong hydrochloric acid, dilute to 1 litre, and well mix. Then measure out two quantities of 20 C. C. each, and determine the hydrochloric acid by means of nitrate of silver. If the two coincide, calculate the amount of hydrochloric acid in 1 C. C. of the solution, and mark the bottle accordingly.

Standard Alkali.—Take 10 C. C. of ordinary potash or soda solution, add a little tincture of litmus, and triturate with standard acid till red. Having thus roughly determined the strength of the solution, dilute a certain quantity of it till one volume will about neutralize one volume of the standard acid. Then, in order to standardize the alkali *exactly*, measure off 20 C. C.; add a little tincture of litmus, and run in the standard acid till the fluid is reddish purple; boil for a minute or two (the blue colour will return if carbonic acid was present), add more acid as required, boil again, and so on till the fluid has a neutral tint not due to carbonic acid. Calculate the value of 1 C. C. of the alkaline

solution and mark the bottle accordingly. To free the alkali from carbonic acid before standardizing it finally, boil it with some slaked lime, allow to settle in a nearly-closed flask, and draw off the clear fluid. Keep the solution in a well-stoppered bottle, or in a bottle through the cork of which a tube containing soda-lime is passed.

The two solutions may be made most advantageously in the following manner. I extract, by permission of the author, the following from Church's "Laboratory Guide," a book which every student of chemistry should have (3rd edition):

"*Acid.*—The acid is a dilute solution of sulphuric acid, of about $\frac{1}{2}$ normal strength; *i.e.*, containing $\frac{1}{2}$ an equivalent of H_2SO_4 ($= \frac{98}{2} = 49$) in grammes in a litre.

Preparation.—Take oil of vitriol, of which the percentage of H_2SO_4 has been pretty nearly found out by its specific gravity. Say it contains 96 per cent. 28 C. C. of this acid, or, of course, an equivalent amount of other acid,

are measured into a beaker, diluted to a litre, and allowed to stand for twelve hours, in order that the lead sulphate may settle : decant the supernatant liquor, and filter the rest. Now ascertain its exact strength. Shake up, and measure into a beaker with the pipette, dilute with 200 C. C. of water and boil with hydrochloric acid. While the liquid is boiling, add gradually a boiling solution of barium chloride: stir well, and add till no further precipitation takes place. Boil the solution till no more barium sulphate falls down, and the liquor is quite clear. Filter the solution, and well wash the precipitate with boiling water. Dry, ignite, and weigh.

The exact amount of $S\,O_3$ per 20 C. C. must now be calculated. It is better to take three assays and strike the mean value.

Alkali.—This is a weak solution of sodium or potassium hydrate, of which 100 C. C. = exactly 20 C. C. of the acid. The caustic soda made from sodium is the best substance to use.

Preparation.—Say we are going to make two litres of alkali solution, out of sodium hydrate. If the acid contains exactly 49 grammes of $H_2 SO_4$ in a litre = ·98 grammes in 20 C.C., since $H_2 SO_4$ saturates 2 $N_a HO$, we have—

$H_2 SO_4$		$2 N_a HO$		in 20 C. C.		in 100 C. C.
98	:	80	=	·98	:	·8 $N_a HO$

C.C.		$N_a HO$		C.C. taken		$N_a HO$ required
100	:	·8	=	a	:	x

Weigh out the amount and add water to about three-quarters of the volume required; now dilute gradually down to the exact standard of 100 C. C. of the alkali = 20 C. C. of the acid.

Keep this solution in well stoppered bottles, in a cold place.

Now determine the exact value of each C. C. of this alkali. Since $H_2 SO_4$ saturates 2 NH_3, if the two solutions are made as above,—

$H_2 SO_4$		$2 NH_3$		in 20 C.C.		NH_3
98	:	34	=	·98	:	·34

Therefore each C. C. of alkali solution $= \frac{\cdot 34}{100} =$ ·0034 gramme of ammonia, or ·0028

of nitrogen, as we have already got 100 C. C. = 20 C. C. of the acid. Suppose, after a nitrogen combustion. the contents of the bulbs require 65 C. C. to neutralize them, it is plain that the acid has absorbed ammonia equal in saturating power to 35 C. C. of the alkali. So 35 × ·0034 = ·119, the weight of ammonia obtained, or 35 × .0028 = ·098 weight of nitrogen, from which the percentage is obtained.

Miller, in his "Elements of Chemistry," gives the following method of estimating the ammonia. 10 grammes of the guano are placed in a small retort, and 100 C. C. of water are added; by means of a bent funnel 25 C. C. of a solution of potash, of specific gravity 1·25, are also introduced; 50 or 60 C. C. of liquid are gradually distilled over into a beaker (by means of a bent tube fixed on to the end of the retort) which contains 100 C. C. of sulphuric acid, diluted to the required strength. As soon as 50 or 60 C. C. have passed over, allow the retort to cool, and 40 C. C. of water are added

to the retort; distil again till this 40 C. C. has passed over, and once more repeat the same operation. A few drops of litmus are now added to the contents of the beaker, and the acid is neutralized by the standard alkali (caustic soda). This solution should be of such a strength that 1 C. C. equals an equal amount of acid solution originally introduced into the beaker.

Suppose, now, this acid solution in the flask requires 67 C.C. of alkali solution, instead of 100. It is evident that 33 C. C. have been neutralized by the ammonia; a quantity of ammonia has passed over therefore = to 3·3 grammes of anhydrous soda. From the two equivalents of the two alkalies, we may calculate the ammonia thus:

$$\begin{array}{ccccccc} Na_2O & & H_3N & & & & \\ 31 & : & 17 & :: & 3·3 & : & 1·809 \times 10 \end{array}$$

or 18·09 per cent. of ammonia in the sample, if 10 grammes are taken. This method is easy, quick, and tolerably accurate.

The alkalies are generally determined by

difference, at least for commercial purposes, but the *phosphorus pentoxyde* should be determined.

The filtrate from the phosphates is concentrated, and a little ammonium oxalate added. If a *decided* precipitate takes place, phosphoric pentoxyde is only present in traces, and need not be looked for any more. If ammonium oxalate produces *no* precipitate, filter the solution if requisite, and treat with magnesium sulphate and great excess of ammonia. Collect, dry, and ignite the precipitate of ammonium magnesium phosphate. The $Mg_2P_2O_7$ is calculated into phosphorus pentoxyde.

A still better method is the following:

The clear and dilute phosphate solution is treated with ammonia in slight excess: dilute acetic acid is added until the precipitate is entirely redissolved. An excess of acetic acid is to be avoided. Any insoluble residue must be removed by filtration. Uranium acetate is now added, and the whole boiled. The uranium phosphate is allowed to subside, and then tho-

roughly washed by decantation, boiling water containing acetate of ammonia being used for this purpose. Finally, get the precipitate on a filter, dry, ignite, and weigh. But before weighing, the precipitate should be moistened with strong nitric acid and ignited again. It should come out a bright yellow; one part = ·1991 of phosphorus pentoxyde.

Concentrate the filtrate and precipitate the uranium by cold ammonia, covering over the vessel. Wash the precipitate twice by decantation, and then boil it with a solution of ammonium chloride. Collect on a filter, and estimate the lime and magnesia as usual."

APPENDIX.

COPPER SMELTING IN CHILE.

To attempt anything approaching a complete account of the mining resources and copper manufactures of Chile would, from obvious reasons, require a very extended experience, and a very intimate acquaintance with the actual working of more than, perhaps, one hundred establishments, at present engaged in such pursuits in that country. The reader may readily imagine the difficulties, almost impossibility, attending such a task, when I state that Chile produces about half the total amount of copper of the whole world, and directly or indirectly employs about half her population in the working of it. In fact, I doubt whether any one man could write a complete account of this subject, in view of the many different principles, systems, and conditions under which establishments are conducted in Chile. As, however, the copper interests of Chile seem to have been strangely misunderstood at home, perhaps a few data on the subject may be of some interest, at least to our home smelters. I premise, first of all, that I cannot wholly guarantee the correctness of all the following statements and deductions, but can only give my readers a general idea of the working and smelting of ores, leaving to them to criticise the correctness of the financial results;

and, secondly, that most of the said data and statements are drawn from a rather exceptional source—the establishment of Guayacan—exceptional for reasons hereafter stated.

Copper smelting, also, seems as yet very imperfectly understood, at least some important facts concerning it. For instance, it has never yet been demonstrated clearly whether an "over-poled" ingot of copper has absorbed carbon, or whether it is due to the total reduction of the dioxyde of copper; in other words, whether a certain amount of oxyde is not essential to its malleability. The precise action of oxyde of copper has never been accurately defined; no one has succeeded in giving a final and decisive reason why an ingot, ladled under certain conditions, rises in the mould; whether it is due to the air of the atmosphere, or sulphurous acid; and why, on the other hand, the ingot sometimes has a slight depression in the centre in cooling in the mould. Imagine the fortune a man might make who would discover a process for getting rid of the sulphur in the operation of making blister, without consuming some tons of coal, and the best part of a day!

One of the cleverest of metallurgists, Le Play, devoted a very considerable portion of his time and talents to the drawing out of elaborate calculations and statements with regard to the smelting of copper, and the profits to be derived from it. As this gentleman had access to several important works in England, his theories were accepted by five unfortunate companies as somewhere near the practica truth, and all five suspended operations after a short existence showing that a man may be a very clever theoretical chemis and yet a very poor smelter and seller. The Mexican an South American Company, which formerly existed in Guay acan Bay, not two miles from the present Guayacan work seemingly started with the fairest prospects; abundar capital, near the richest mines in the world, with a goo

harbour, and good smelters, including Mr. Francis, the present head smelter at Guayacan. Yet it failed, and people blamed the system of smelting, the fact being that the very same system is at present employed at Guayacan. The real cause of failure of that company was bad management and distance from their base of operations, the board of directors being in England; consequently, disputes which are easily settled when the chiefs are on the spot, promise to be endless when lengthy and tedious correspondence has to be carried on with the home board. Anyone who knows the unceasing activity, above all other things, which the management of a copper works requires, can readily understand the defect of such a system. Shortly before the company subsided, a *lawyer* was actually sent out from England to take charge of the works. The result can easily be imagined.

The system of smelting pursued at Guayacan differs materially from any other. It is what is called "Napier's improved process." The great advantage the Chile smelters here have is that they are enabled, by their "coloured" ores, to bring up the ley of the regulus at one operation to a pitch of 45 or 50 per cent., thus saving an immense deal of time and trouble.

As regards the financial results, I may as well state that having been connected with the Guayacan Copper Works, I am not at liberty to enter into very particular details as regards profits, &c. One of the very best smelters in Chile, however, told me that as a general rule companies must be satisfied with 7 per cent. on their capital. Indeed, statements about copper smelting are so contradictory that it is useless to try and give a rule for the regulation of profits. Some people think that all a smelter has to do is to put the ores into the furnace and tap out copper and 15 per cent. dividends; the fact being that as much depends on the

financial as on the smelting operations. I have premised so much as a sort of apology for, I daresay, some few errors in my calculations and statements. Of course, everyone, down to the office-boy in a copper works, thinks he knows all about smelting, but I am quite sure I could enumerate all the good smelters I know on my five fingers. We will take first the ores, then the furnaces, and then the mode of smelting, and prices.

ORES.—All ores in Chile are divided into two classes, bronces and color—sulphurets and carbonates. There are several sorts of sulphurets. First, the yellow sulphurets, with quartz and silica as their basis; most of these come from the north of Chile. Secondly, those with lime and silica for their base; these come principally from Tamaya and that neighbourhood. And we have also the bronce morado (purple ore), and the black sulphuret (bronce negro); the former principally from the Tamaya region, and the latter from different parts of the province of Coquimbo.

The carbonates, or "color" ores, contain, of course, a minimum of sulphur. Those which have much silica in their composition, and are difficult of fusion, are called "secos," or dry metals; these form the largest portion of the ores. Those which contain a good deal of carbonate of lime or iron, and are easily fused, are called "blandos," or soft. Besides these we have a good deal of the carbonate ore known as color bronceado, and other kinds of ore bought from the "Pirquineros" in small lots.

The source from which the ores used at Guayacan is derived is the Tamaya region, the most important of the mines belonging to Mr. Urmeneta, the head partner of Guayacan. The average ley of the whole Tamaya region may be put at from 15 to 16 per cent., and the whole production as something over 45,000 English tons yearly. The class of ore principally produced is a sulphuret, very pure

in quality, and free from injurious metals, such as arsenic, antimony, &c. Carbonates are principally obtained from the Sarco district, which produces ores of an exceeding purity and richness. Carrizal also sends large quantities of yellow sulphurets.

One of the great advantages which Guayacan has over other establishments is that the ores are very pure, and are usually in such abundance that the smelter can afford to pick and choose, instead of, as is frequently the case, having to put up with whatever he can get. Although, as I stated above, the average ley of the ores smelted at Guayacan may be put down at 15 per cent., yet another company on the coast would have to reckon on 12 per cent. as the outside limit of the ores at their disposal. So much then for the ores.

FURNACES.—The universal furnace used throughout Chile is the ordinary reverberatory one. The furnaces at Guayacan are constructed to hold, more or less, 8 tons, the charge consisting of two lots of 4 tons each; the first one is melted down in the usual manner, cleaned, &c., and the second one is introduced. The furnace is then manipulated in the ordinary manner, and is tapped on *two* charges. At Carrizal the furnaces of the company are somewhat larger, being built to hold charges of 9 or 10 tons. The following are the dimensions of an ordinary furnace:—

Length outside, including grate	Feet	28	0
Width outside		16	0
Grate		6	0
Length inside to bridge		18	0
Breadth in middle		12	0
Breadth in mouth		2	0
Breadth in bridge		5	7
Height in middle } from bricks		3	7
Height in mouth } from bricks		2	5
Height in bridge } from bricks		4	0
Length of bridge inside		5	7
Length of bridge outside		4	0

Height of bridge	Feet	2	0
Breadth of bridge		2	7
Fire-place 4 feet square inside.			
Height from top of bridge to roof		2	0
Width of flue is 18 inches.			
The thickness of the sides is two bricks and a half.			

Slope, from grate to hole, 30 inches, or 7 bricks; the corners are filled in solid; the bed is formed of 12 inches of quijo, or crushed quartz. A furnace will take about 30,000 bricks (if with culverts), and, more or less, 150 qntls. of iron in its construction. Its cost may be put down at about £600 in complete running order.

There are two refineries at Guayacan, one holding 14 tons and the other 20 tons. Out of this latter over 2000 ingots have been ladled, averaging 100 to the ton. They are of the same construction as the others, but they are, of course, fed by side holes, and not by hoppers. The calciners at Guayacan are about 40 ft. long, including grate and all. They are constructed with three consecutive floors, divided from each other by a bridge, and each a few inches lower than the one above. Over the first, or one farthest from the fire, is placed the hopper; into this the charge is put, consisting of 4 tons of regulus. After a calcination of from 10 to 12 hours in the first floor it is raked down by paddles to the second floor below, and there calcined 10 hours. Meanwhile, another fresh charge is placed on the first floor, and the one on the second raked down to the third, and so on, following each other. After about 35 hours calcining in all, the lowest floor, or one nearest the fire, is raked out through a hole in the side into a pit below; water is then thrown on it, and it is ready for the bar furnace mixtures; this calcined regulus has now about 3 per cent. of sulphur. There are 17 of these furnaces at Guayacan. Brunton's revolving calciner was also tried, but after a short trial was abandoned. Great care must be taken to regulate the heat

of these calciners so as not to let the regulus *cake*, which would delay its thorough calcination. This accident can be easily avoided by taking care that the charge next the fire is heated as much as possible without caking; in this case the other charges will have just the required heat. Many furnaces are prematurely ruined by being used too soon after building. The proper course is to let the wooden props used in its construction burn slowly away, and the length of time required for a furnace to dry is, at least, eight days with a slow fire. The bricks used are principally Lota, and Dinas when they can get them. The difference between them is enormous: a roof constructed of Lota will burn through in a fortnight, while one of Dinas bricks will stand six months.

The coal comes principally from the south of Chile—Lota and Lebu; some English coal is also used for the refinery. In the big 20-ton refinery a sufficient heat could not be got on with the Chile coal, but it answered very well with the smaller 14-ton furnace. Puchoco "lower vein" is one of the best smelting coals when pure; there are two sorts, "upper" and "lower," and the company are supposed to sell "half-and-half." The coal from Coronel is a very dull, slow coal, and that from Lebu is 25 per cent. dirt. Some experiments were carried out to ascertain the proportionate value of the different classes of coal, and it was discovered that the average Chile coal, if tolerably pure, was at the price nearly equal to English. We will consider the pay of the workmen as we describe the operations in each furnace.

Supposing, then, that we have our furnace in running order, we proceed as follows:—Before charging the furnace we throw in a quantity of slag to fill up the interstices at the bottom; when this slag is melted we introduce the charge. Supposing everything has proceeded satisfactorily, we tap

out and examine the slags; in them we may find pieces of regulus, or shots of copper. If we find regulus we may be pretty certain that the slag has not been sufficiently fluid to allow the regulus to fall to the bottom; we, therefore, must add more ferruginous ores to our mixture, and take care that we get sufficient heat on the furnace. If, however, we find shots of copper in our slag, we know that there has not been sufficient sulphur in our mixture to reduce the oxyde and form regulus, and, therefore, we must add more sulphurets.

While the charge of regulus is still running out, the bottom of the bin is pulled out, and the fresh charge allowed to fall into the furnace; it is then spread evenly all over the bottom, the door closed, the bin closed up, and a fresh charge placed in it ready for use, and all the openings, &c., stopped up with clay. If, however, the ores contain a great abundance of sulphur the door is left open for them to calcine a little. The charge now roasts itself, but great skill is required in attending to the fire to regulate the heat with as little coal as possible, as the test of good smelting is the proportion of coal to ores smelted. The whole operation for one charge takes about four hours, with good coal and average ores. At this point the smelter takes down the door, and examines the charge: he stirs it well, skimming off lumps of quartz and other matters that are not fusible, scraping up the bottom, &c. The furnace is again closed and the fire pushed on briskly, when it is skimmed, care being taken that no regulus is taken off with the slags, and that a thin layer is left to cover the regulus on top. After this the fire is urged for a few minutes to its utmost, and the furnace is then tapped into sand-moulds. After frequent smeltings with ferruginous ores the furnace will get corroded, especially by the "wash" of the metal; this is caused by the silica in the bricks combining with the iron in the ores.

These defective places are repaired by crushed quartz, or, as it is called, quijo.

It will be seen that copper is obtained by this method at one operation. The regulus made is of an excellent quality and of an average ley of 48 per cent. It will be frequently observed that a grate may get a very good heat on, almost enough to melt the bars, and yet there is comparatively little heat in the *ore*. The reason is that there is need of more room, or "play," in the stack for the current of air. Gerstenhoffers were tried at Guayacan, but it was found that they did not bring regulus far enough on—in other words, did not calcine it sufficiently; consequently, in the bar charges so much sulphur remained in the regulus that the charge came out almost all white metal. I am informed, however, that these calciners are only used as a partial process in Germany, and at Guayacan they misunderstood them altogether: anyhow, they were found too expensive for Chile, where economy is everything.

I shall now consider the operations of making regulus, bar copper, blister, and ingot, in their order.

OPERATION I.—*Making Regulus.*—In this operation we must have yellow sulphurets in our mixture; if, however, we were to smelt these alone we should only get a regulus of about 25 per cent., or at most 30 per cent.; if we calcined them in the open air the percentage would reach 45 or 48 per cent. of copper, which ley would ensure good slags. If we can secure plenty of good bronce morado, or metal de color, for making our mixture, we need not calcine the ore, unless we wish to liberate iron in order to flux the silica, so as to get a good slag; so that if we have abundance of yellow sulphurets with no *free* iron in their composition, or which contain a large amount of silica, calcination is required. The objects to be attained in this operation are (1) a charge easily fused, and which gives good slags; and (2) a charge

which will give a regulus more or less of 50 per cent. Generally speaking a charge will contain from ⅓ to ½ its quantity of yellow sulphurets, because the quality of the regulus depends on the relative quantity of sulphur and copper in the ore. We now have our regulus; the next step is—

OPERATION II.—*Making Bar Copper.*—The furnace is precisely the same as for the first operation. The regulus is first taken to a mill and crushed; the mills in use at Guayacan are the old-fashioned cylindrical rolls of a very ancient type, and crush about 90 tons of soft regulus a day; the powdered regulus is then passed through a sieve of 64 holes to the square inch. It is then placed in the calcining furnaces, as described above, and calcined for about 35 or 40 hours, to extract the sulphur, or, rather, all but about 3 per cent. When the powdered regulus is put in the furnace its composition is about as follows: 50 per cent. of copper, 25 of iron, and 25 of sulphur, equal to 100 per cent. And when taken out—50 per cent. of copper, and 25 of iron, oxydized; and 3 per cent. of sulphur. The charge for making bar copper is, more or less, as follows:

Regulus...Qtls.	27·00	or	Regulus...Qtls.	27·50	Average ley, 35·5 per cent.
Sulphurets......	1·52	,,	Sulphurets......	2·05	
Carbonates.....	7·48	,,	Carbonates.....	7·15	
Slags...	4·00	,,	Slags...........	3·85	
Coal .... / Cinders	3·00	,,	Coal..........	1·10	Fluxes.
			Cinders.......	1·55	
	Qtls. 43·00			Qtls. 43·20	

As the furnace is tapped on two charges we get, more or less, the following result:

17·20 kilos. bar copper .... = 97 per cent.
14·70 kilos. white metal .... = 65 per cent.

Expressed as follows: Charge (not including fluxes), 75 qtls.

by 35 per cent. (·5 being allowed as loss) = 26·25 fine copper = tap out.

17·20 kilos. bar, at 97 per cent..............	=	16·69 kilos.
14·70 kilos. white metal, at 65 per cent....	=	9·56 kilos.
31·90 kilos.	Fine copper.	26·25 kilos.

A furnace in full work turns out in the day about 56·00 kilos. of bar and white metal in the above proportions. In these furnaces 2 tons of ore are smelted to 1 ton of coal. Of course it will be seen that the oxyde of iron in the calcined regulus combines with the silica in the carbonates, forming a fusible slag. The coal and cinders are added to reduce the copper. The same precautions are necessary in the skimming and tapping of these furnaces as noted in the former ones. From all the carbonate ores we get copper at *one* operation, but as the regulus is, of course, not totally calcined, and the ores contain sulphur as well, we get a large amount of "white metal," which is subsequently roasted into blister, and afterwards refined into ingots. We might, however, if we chose, refine the bars at once, in 7 or 8 ton charges, in from 20 to 24 hours. From 17 to 18 bars are produced in each tapping, or (say) 3 tons in the 24 hours. The slag, &c., from the tappings come in from fluxes in other charges; the guaranteed ley of the bars is 96 per cent., and they generally reach 97·5 percent. Sometimes there is danger of some regulus getting "layered" in between the solid copper, by reason of a bad and thick slag, and thereby deteriorating both the ley and the quality of the bars. The bars average about nine to the ton. The relative proportion of ingots and bars produced in an establishment turning out 8000 tons a year, would be, more or less, as 3 to 5, or 3000 tons ingots and 5000 tons bars. The principal reason why the regulus is calcined so much is because there is not sufficient coloured metals to carry off the superfluous sulphur

which the regulus would have if not calcined. The metales bronceados, having but little oxygen and sulphur, are of course mixed up in small quantities with the other ores. The operations that take place in the furnace are as follows: the coal and cinders will reduce the copper which falls to the bottom of the furnace, the sulphur combines with the oxygen of the air and goes off as sulphurous acid, and the silica combines with the iron in the ore and forms a fusible and liquid slag. Supposing the ley of our bars comes out low, or below guaranteed value of 96 per cent., we must continue a low heat for some considerable time, and the furnace must be well rabbled up, with the addition, if possible, of more green carbonates and reducing agents to our mixture; if, however, we find the ley of our bars too high—that is to say, 98 or 99 per cent.—we know that we have reduced too much oxyde of copper; this was the reason why the *old* Chile bars were so superior to the present ones; the old smelters were too poor to put up calciners, crushers, &c., and so they had to put their ores in raw,—in "colpas," smelting them with wood; the carbon in the wood fire reduced more oxyde and sulphur, and the ley of the bars consequently rose to 99 per cent. frequently, but the smelter was only paid, as now, for 96 per cent. The old smelters, when their metals were poor, used to run down two charges and then introduce a *third* charge of rich carbonates on top, and tap on three.

Two men only work each of the above-mentioned calciners, charging, coaling, paddling, and everything; they work each 24 hours on a stretch, and are paid $2, or 8*s*., each.

The bar furnaces have two *maestros*, or masters, and two helpers (*officiales*) each, working 24 hours. The masters get 2c. a Spanish quintal on all the ores put in the furnace, and they have to pay out of this $1 to each of the two helps.

Supposing, then, that a charge consists of 70 qntls., and we smelt 3½ charges a day, if a furnace is in good working trim, a master's pay would be 150 qntls. by 4·3-10ths c. (equivalent to 2c. Spanish), which amounts to \$6·50c., or less \$2 for the two helps = \$4·50c., or \$67·50c. a month. The helps really earn only 7 reals, or 3*s.* 6*d.* each, as the real, or 6*d.*, is left towards charging the furnace at night. The bars, when they leave the beds, are covered with spots of regulus, dirt, sand, &c., and are cleaned and trimmed by contract at the rate of 8c. per 3 bars. Two tappings a day is considered good work, which is about equal to 3 tons of bar copper; this amount would not be obtained unless with first-rate coal, as bad coal necessitates frequent skimming and removing of the door, which cools the furnace and throws it back. The large cake at the mouth-bed of the furnace is always broken up and used in the charges again; it contains a good deal of quijo, copper, regulus, &c. The first and second beds on each side of the furnace mouth also contain a good deal of regulus, which comes out with the unmelted quijo and quartz; they also are, of course, resmelted.

OPERATION III.—*Making Blister Copper.*—The charge consists, more or less, of 7 tons of white metal from the bar furnaces, introduced into a furnace constructed precisely like the latter, with the exception of having two air-holes on each side of the bridge, diagonally directed over the charge. To commence with, the air-holes are opened and the fire pushed on brisk, whilst the charge gradually melts down, which should be in about six hours; it drips down like melted bacon, and when it is melted the air-holes are closed tightly and the fire raked up to form a slag, which rises in about four hours, and is carefully skimmed off; when the face of the bath is pretty well cleaned, the front door is put up and the air-holes opened again, which cools the furnace slightly and cakes the slag, which so can be easily cleaned

off. This latter slag is very rich, and carries off most of the impurities, as antimony, arsenic, &c., &c.; the charge is then allowed to roast again, and is again skimmed, as soon as a slag forms, as at first; this usually happens three times. After the first skimming the metal begins to "work"—*i.e.*, boil up with a frizzling sound exactly like a frying-pan of melting fat—the furnace being kept at such a heat as to keep the metal in a *half-viscid state.* At the end of 24 or 30 hours, according to the fineness of the metal put in, the white metal gradually boils off the face of the copper below, and the latter, as its face clears, changes its frizzling, pasty appearance, and appears exactly like a pool of water into which rain-drops are continually falling; should there be any holes or faulty places in the furnace bottom the copper will boil up from them like a miniature volcano, and the smelter must not be alarmed at this symptom. From this point the bath must be constantly watched. Generally, in one and a half or two hours after it has assumed the last-mentioned appearance the surface of the copper gets gradually more and more quiescent, until at last (with the exception of the before-mentioned volcanoes, if the bottom be faulty) it becomes perfectly smooth. Now is the critical time, for if the operation has been well conducted there ought to appear in about a quarter of an hour afterwards a slight ripple on the surface of the bath, just like a ruffled pool, accompanied by a peculiar dark scaly substance floating on the top. Immediately this appears, the air-holes are closed and the fire pushed on for 10 minutes, when the furnace is tapped out into sand moulds as blister copper. If it has been tapped too soon there will be formed miniature fountains in the beds, caused by the sulphur trying to force its way out. Good metal takes about 24 hours to roast, and requires more heat on, and coarse metal about 30 hours. Supposing a charge of 7 tons is taken, about 5 tons

of blister will be obtained. In this operation the whole of the iron and most of the sulphur are driven off, the former being skimmed off with the slag, and the sulphur, combining with the oxygen of the air, going off in the form of sulphurous acid. What little sulphur does remain is subsequently roasted off in the operation of refining. These roasters are fed by a side hole, and have no hopper. By reason of the continued heat to which the furnace is subjected, the bottom frequently rises very much—that is, it cakes, and the copper gets under and raises it up, entailing a loss of copper in the tapping, and the bed gets extremely hard and difficult to break up. A roaster bed will absorb sometimes as much as 15 tons of copper. *Loza*, or broken sea shells, is found to stand better than anything else, though some smelters use plain brick floors with fair results.

In Germany they use an iron floor supported on four columns, and build the bed of the furnace on that; supposing the copper goes through, it cools before reaching the ground underneath. Four men charge the roasters and carry away the pigs, &c., to their destination; 6 reals, or 3*s*., is paid for charging a roaster, and so much a bed for moving. The "sharp" slag from the roasters averages about 10 per cent., and the "roaster" slag about 30 per cent., all of which is of course returned to the bar furnaces. The men who attend to the roasters are also employed at the refinery, and are paid $50 per month; 7 reals, or 3*s*. 6*d*., is paid to the helper, or *official*, as he is called, per day of 12 hours, exclusive of the pay for charging the furnace. Sometimes the furnace will not stand the requisite heat for bringing on the copper to blister, in which case it is brought on to *sponge* copper only. It is rather curious that the slag gets thicker the farther it gets towards sponge, and thinner from sponge to blister; this is owing, I presume, to the greater heat.

OPERATION IV.—*Refining for Ingots.*—The charge consists of four beds of the roasters, or 20 tons blister copper. The time generally required to refine the charge is about 16 or 17 hours. Four hours before charging, a large quantity of cactus root is thrown in at the door of the furnace, and two or three hours after the bath is well poled. This operation is conducted by protruding] a pole of *lumas* wood through the door of the furnace, and pressing it well over to the bottom, in order to expose as much as possible of the copper to the action of the carbon; it usually takes about an hour's poling to bring the copper up to the proper pitch. The face of the bath is then covered with fine anthracite coal, to prevent oxydation by the air, and the metal is then ready for ladling. The object of the poling is, of course, to reduce the oxyde that is contained in the melted copper, and upon the excellence of the poling does the refining greatly depend; the presence of an oxyde would, of course, render the copper brittle. Usually two tests are taken to ascertain if the copper is at a proper pitch. They are taken as follows: Two ladles, lined with clay, are filled with copper from the furnace, and placed to cool in a horizontal position. If the copper is at the right pitch, these tests should set perfectly free from the smallest trace of rising or volcanoes, and when perfectly cool should contain a slight circular depression in the centre about ⅛ in. deep, in a 20-lb. ladle. The surface must not present any appearance of longitudinal or horizontal depressions or lines, but that of, more than anything else I can liken it to, a piece of coarse wrinkled skin, the wrinkles extending in no particular direction. An ingot when cooled should be as near as possible flat, slightly wrinkled, and the rim slightly raised all round equally—in fact, a good ingot (for alloys) may be compared to an oblong pool of water almost full. In pouring an ingot into the mould care must be taken to pour

evenly and gradually, or the appearance of it will be spoiled. The copper is ladled as quickly as possible by four or five men at a time, to prevent the bath of metal going out of pitch. To prevent this during ladling some billets of wood are thrown in at the door of the furnace; but even with every precaution the copper sometimes goes back, entailing sometimes two or three hours to bring it on again: 100 copper moulds are ranged on iron chairs round the front of the furnace, each round being, more or less, a ton of ingots. Besides these there are the moulds themselves to be made, which contain two ladles full of copper apiece; three of these are run at the end of each round, so that in a 19-ton charge 57 moulds would be made; for making these the men get no extra pay.

In the large 20-ton refinery English coal is burnt, as it was found that a sufficiently strong heat could not be got on the furnace with Chile coal; but in the new 14-ton refinery Chile coal does well enough. The large furnace consumes about 5½ tons of coal in a day, and 1 ton of anthracite coal for every 50 tons of ingots produced. The number of *lumas* poles required may be put down as one pole to every 1½ ton of copper, and taking a copper works all through about 3½ tons of coal are required to produce a ton of fine copper. The cactus roots, mentioned above, contain a good deal of moisture, and, as it is technically called, "cools" the copper. In charging the refinery care must be taken to clean the blister well, to prevent the sand rising and mixing with the slag; this arises from carelessness in stepping in the sand moulds when made. After the furnace has been poled it is skimmed perfectly clean: this throws it back a little, but the coal subsequently thrown on brings it on again; the fire has meanwhile not been banked up, but if the test ingot is satisfactory the fire is stuffed quite tight before ladling.

Four men charge the furnace, and 12½c. are paid per ton for charging. A royalty of 62½c. a ton is paid to the ladlers, who, as before stated, receive $50 a month wages for the roasters as well. It costs as near as possible $5 per ton to refine copper; roasting costs about the same, calcining, more or less, $3·50 the ton, and crushing about 27c. or 30c. Conversion from regulus to bar may be calculated at from $4 to $4·50 a ton.

The loss in a copper works all through may be put down at somewhere about 1½ per cent. One of the most astonishing things connected with this subject is the enormous amount that gets collected in the culverts. In large works, producing 9000 tons a year, the quantity amounts to not less than 350 *tons* annually of an average ley of 35 per cent.; of course this is recovered and re-smelted. The question arises, how much goes out of the chimneys?

As regards profits to be made by copper smelting, it is impossible to give anything like a correct idea, as everything depends on management; in fact, I would be bound to say that anyone might have access to the books of the most successful company, and yet start for himself and lose money. A great deal depends on the different systems pursued. I may, however, state that ·78c. is usually considered an average price for reducing 1 quintal of 15 per cent. ores to regulus, and about $40 to $42 for reducing regulus to bar copper, per ton of fine copper. Generally speaking, however, companies would have to calculate $1 and $46 respectively. This formula is supposed to cover all expenses after the ore is actually on the ground. Supposing, then, we take 68 quintals of 15 per cent. ore, it will give us about 1 quintal fine copper, allowing for trifling waste. Supposing we pay for it at the rate of, say, 1·42c. for 10 per cent. with a ·23c. rising scale, we get, more or

less, as the value of the ores, \$175·00. Adding a trifle less than a dollar for conversion to regulus, we get, say, \$240·00 in the form of regulus; with an addition of \$45 for conversion to bar, we have \$285·00; bar copper being quoted on shore at \$297·00, this leaves a profit of \$12, or £2 10*s.*, more or less, a ton; that is to say, that a company turning out 5000 tons of ingots and bars ought to show a profit of from £12,000 to £15,000 a year. It is obviously impossible to give any formula, however. Supposing, for instance, a smelter has a contract with a large mine to deliver so many tons a month for one year at a fixed price; copper goes up £15 a ton, and the smelter, of course, as he does not pay any more for labour or coal, reaps the entire benefit of this rise. Ores are bought in Chile either at a fixed contract price, or by the price quoted of bar copper, allowance being made for the conversion of the ores to copper. When it is sold at a fixed rate, a point is taken, say of 10 per cent. Thus, 10 per cent. is worth, for example, 140c., and for every unit over 10 per cent. 25c. is paid; then for 12 per cent. ores of course 140 + 50c. = 190c. would be paid, and so on. When regulated by the price of copper, an example may be given thus: When bar copper is quoted 14·40c. a Spanish quintal on the coast, 65c., more or less, would be paid for a quintal of 10 per cent., and 13c. for every unit over placed in smelter's establishment. So we have on 15 per cent. ores, 10 = 65 and 5 × 13 = 65 = \$1·30 for 1 quintal of 15 per cent. ores, Spanish weight. Now, 147 Spanish quintals are required, more or less, to produce a ton of fine copper, so multiplying 147 by 1·30 = \$191·10, adding 78c. and \$42 respectively for conversion, we have an apparent profit of \$24, as copper is subject to a 33c. reduction for duties, &c., which makes the price \$14·40—·33 = \$14·17 as price o f1 ton of copper on shore. Interest, commission, brokerage, loss, &c.,

must be deducted from this. As regards costs of works, &c., I have been informed that an establishment capable of turning out 8000 tons yearly could not be erected under £30,000 to £40,000, and the capital required to carry it on should not be less than £100,000. By no known method, I believe, can money be so quickly lost as in copper works badly managed, but that copper-smelting in Chile, properly managed, pays, and pays well, I have no doubt.

TABLES

FOR DETERMINING THE STANDARD OF ANY SILVER ALLOY BY EMPLOYING AN AMOUNT OF ALLOY APPROXIMATELY CONTAINING THE SAME AMOUNT OF SILVER.

TABLES FOR DETERMINING THE STANDARD OF ANY SILVER APPROXIMATELY CONTAINING

NITRATE OF

Weight of Assay in Milligrs.	0	1	2	3	4
1000	1000·0	999·0	998·0	997·0	996·0
1005	995·0	994·0	993·0	992·0	991·0
1010	990·1	989·1	988·1	987·1	986·1
1015	985·2	984·2	983·2	982·3	981·3
1020	980·4	979·4	978·4	977·4	976·5
1025	975·6	974·6	973·7	972·7	971·7
1030	970·9	969-9	968·9	968·0	967·0
1035	966·2	965·2	964·2	963·3	962·3
1040	961·5	960·6	959·6	958·6	957·7
1045	956·9	956·0	955·0	954·1	953·1
1050	952·4	951·4	950·5	949·5	948·6
1055	947·9	946·9	946·0	945·0	944·1
1060	943·4	942·4	941·5	940·6	939·6
1065	939·0	938·0	937·1	936·1	935·2
1070	934·6	933·6	932·7	931·8	930·8
1075	930·2	929·3	928·4	927·4	926·5
1080	925·9	925·0	924·1	923·1	922·2
1085	921·7	920·7	919·8	918 9	918·0
1090	917·4	916·5	915·6	914·7	913·8
1095	913·2	912·3	911·4	910 5	909·6
1100	909·1	908·2	907·3	906·4	905·4
1105	905·0	904·1	903·2	902·3	901·4
1110	900·9	900·0	899·1	898·2	897·3
1115	896.9	896·0	895·1	894·2	893·3
1120	892·9	892·0	891·1	890·2	889·3
1125	888·9	888·0	887·1	886·2	885·3
1130	885·0	884·1	883·2	882·3	881·4
1135	881·1	880·2	879·3	878·4	877·5
1140	877·2	876·3	875·4	874·6	873·7

ALLOY BY EMPLOYING AN AMOUNT OF ALLOY ALWAYS THE SAME AMOUNT OF SILVER.

SILVER.

5	6	7	8	9	10
995·0	994·0	993·0	992·0	991·0	990·0
990·0	989·0	988·1	987·1	986·1	985·1
985·1	984·2	983·2	982·2	981·2	980·2
980·3	979·3	978·3	977·3	976·4	975·4
975·5	974·5	973·5	972·5	971·6	970·6
970·7	969·8	968·8	967·8	966·8	965·8
966·0	965·0	964·1	963·1	962·1	961·2
961·3	960·4	959·4	958·4	957·5	956·5
956·7	955·8	954·8	953·8	952·9	951·9
952·1	951·2	950·2	949·3	948·3	947·4
947·6	946·7	945·7	944·8	943·8	942·9
943·1	942·2	941·2	940·3	939·3	938·4
938·7	937·7	936·8	935·8	934·9	934·0
934·3	933·3	932·4	931·4	930·5	929·6
929·9	929·0	928·0	927·1	926·2	925·2
925·6	924·7	923·7	922·8	921·9	920·9
921·3	920·4	919·4	918·5	917·6	916·7
917·0	916·1	915·2	914·3	913·4	912·4
912·8	911·9	911·0	910·1	909·2	908·3
908·7	907·8	906·8	905·9	905·0	904·1
904·5	903·6	902·7	901·8	900·9	900·0
900·4	899·5	898·6	897·7	896·8	895·9
896·4	895·5	894·6	893·7	892·8	891·9
892·4	891·5	890·6	889·7	888·8	887·9
888·4	887·5	886·6	885·7	884·8	883·9
884·4	883·6	882·7	881·8	880·9	880·0
880·5	879·6	878·8	877·9	877·0	876·1
876·7	875·8	874·9	874·0	873·1	872·3
872·8	871·9	871·0	870·2	869·3	868·4

NITRATE OF

Weight of Assay in Milligrs.	0	1	2	3	4
1145	873·4	872·5	871·6	870·7	869·9
1150	869·6	868·7	867·8	867·0	866·1
1155	865·8	864·9	864·1	863·2	862·3
1160	862·1	861·2	860·3	859·5	858·6
1165	858·4	857·5	856·6	855·8	854·9
1170	854·7	853·8	853·0	852·1	851·3
1175	851·1	850·2	849·4	848·5	847·7
1180	847·5	846·6	845·8	844·9	844·1
1185	843·9	843·0	842·2	841·3	840·5
1190	840·3	849·5	838·7	837·8	837·0
1195	836·8	836·0	835·1	834·3	833·5
1200	833·3	832·5	831·7	830·8	830·0
1205	829·9	829·0	828·2	827·4	826·6
1210	826·4	825·6	824·8	824·0	823·1
1215	823·0	822·2	821·4	820·6	819·7
1220	819·7	818·8	818·0	817·2	816·4
1225	816·3	815·5	814·7	813·9	813·1
1230	813·0	812·2	811·4	810·6	809·8
1235	809·7	808·9	808·1	807·3	806·5
1240	806·5	805·6	804·8	804·0	803·2
1245	803·2	802·4	801·6	800·8	800·0
1250	800·0	799·2	798·4	797·6	796·8
1255	796·8	796·0	795·2	794·4	793·6
1260	793·6	792·9	792·1	791·3	790·5
1265	790·5	789·7	788·9	788·1	787·3
1270	787·4	786·6	785·8	785·0	784·2
1275	784·3	783·5	782·7	782·0	781·2
1280	781·2	780·5	779·7	778·9	778·1
1285	778·2	777·4	776·6	775·9	775·1
1290	775·2	774·4	773·6	772·9	772·1
1295	772·2	771·4	770·7	769·9	769·1
1300	769·1	768·5	767·7	766·9	766·1
1305	766·3	765·5	764·7	764·0	763·2

SILVER—*continued.*

5	6	7	8	9	10
869·0	868·1	867·2	866·4	865·5	864·6
865·2	864·3	863·5	862·6	861·7	860·9
861·5	860·6	859·7	858·9	858·0	857·1
857·8	856·9	856·0	855·2	854·3	853·4
854·1	853·2	852·4	851·5	850·6	849·8
850·4	849·6	848·7	847·9	847·0	846·1
846·8	846·0	845·1	844·3	843·4	842·5
843·2	842·4	841·5	840·7	839·8	839·0
839·7	838·8	838·0	837·1	836·3	835·4
836·1	835·3	834·5	833·6	832·8	831·9
832·6	831·8	831·0	830·1	829·3	828·4
829·2	828·3	827·5	826·7	825·8	825·0
825·7	824·9	824·1	823·2	822·4	821·6
822·3	821·5	820·7	819·8	819·0	818·2
818·9	818·1	817·3	816·5	815·6	814·8
815·6	814·7	813·9	813·1	812·3	811·5
812·2	811·4	810·6	809·8	809·0	808·2
808·9	808·1	807·3	806·5	805·7	804·9
805·7	804·9	804·0	803·2	802·4	801·6
802·4	801·6	800·8	800·0	799·2	798·4
799·2	798·4	797·6	796·8	796·0	795·2
796·0	795·2	794·4	793·6	792·8	792·0
792·8	792·0	791·2	790·4	789·6	788·8
789·7	788·9	788·1	787·3	786·5	785·7
786·6	785·8	785·0	784·2	783·4	782·6
783·5	782·7	781·9	781·1	780·3	779·5
780·4	779·6	778·8	778·0	777·3	776·5
777·3	776·6	775·8	775·0	774·2	773·4
774·3	773·5	772·8	772·0	771·2	770·4
771·3	770·5	769·8	769·0	768·2	767·4
768·3	767·6	766·8	766·0	765·2	764·5
765·4	764·6	763·8	763·1	762·3	761·5
762·4	761·7	760·9	760·1	759·4	758·6

NITRATE O'

Weight of Assay in Milligrs.	0	1	2	3	4
1310	763·4	762·6	761·8	761·1	760·3
1315	760·5	759·7	658·9	758·2	757·4
1320	757·6	756·8	756·1	755·3	754·5
1325	754·7	754·0	753·2	752·4	751·7
1330	751·9	751·1	750·4	749·6	748·9
1335	749·1	748·3	747·6	746·8	746·1
1340	746·3	745·5	744·8	744·0	743·3
1345	743·5	742·7	742·0	741·3	740·5
1350	740·7	740·0	739·3	738·5	737·8
1355	738·0	737·3	736·5	735·8	735·1
1360	735·3	734·6	733·8	733·1	732·4
1365	732·6	731·9	731·1	730·4	729·7
1370	729·9	729·2	728·5	727·7	727·0
1375	727·3	726·5	725·8	725·1	724·4
1380	724·6	723·9	723·2	722·5	721·7
1385	722·0	721·3	720·6	719·9	719·1
1390	719·4	718·7	718·0	717·3	716·5
1395	716·8	716·1	715·4	714·7	714·0
1400	714·3	713·6	712·9	712·1	711·4
1405	711·7	711·0	710·3	709·6	708·9
1410	709·2	708·5	707·8	707·1	706·4
1415	706·7	706·0	705·3	704·6	703·9
1420	704·2	703·5	702·8	702·1	701·4
1425	701·8	701·0	700·3	699·6	698·9
1430	699·3	698·6	697·9	697·2	696·5
1435	696·9	696·2	695·5	694·8	694·1
1440	694·4	693·7	693·1	692·4	691·7
1445	692·0	691·3	690·7	690·0	689·3
1450	689·7	689·0	688·3	687·6	686·9
1455	687·3	786·6	685·9	685·2	684·5
1460	684·9	684·2	683·6	682·9	682·2
1465	682·6	681·9	681·2	680·6	679·9
1470	680·3	679·6	678·9	678·2	677·5

SILVER—*continued.*

5	6	7	8	9	10
759·5	758·8	758·0	757·2	756·5	755·7
756·6	755·9	755·1	754·4	753·6	752·8
753·8	753·0	752·3	751·5	750·8	750·0
750·9	750·2	749·4	748·7	747·9	747·2
748·1	747·4	746·6	745·9	745·1	744·4
745·3	744·6	743·8	743·1	742·3	741·6
742·5	741·8	741·0	740·3	739·5	738·8
736·8	739·0	738·3	737·5	736·8	736·1
737·0	736·3	735·6	734·8	734·1	933·3
734·3	733·6	732·8	732·1	731·4	730·6
731·6	730·9	730·1	729·4	728·7	727·9
728·9	728·2	727·5	726·7	726·0	725·3
726·3	725·5	724·8	724·1	723·4	722·6
723·6	722·9	722·2	721·4	720·7	720·0
721·0	720·3	719·6	718·8	718·1	717·4
718·4	717·7	717·0	716·2	715·5	714·8
715·8	715·1	714·4	713·7	712·9	712·2
713·3	712·5	711·8	711·1	710·4	709·7
710·7	710·0	709·3	708·6	707·9	707·1
708·2	707·5	706·8	706·0	705·3	704·6
705·7	705·0	704·3	703·5	702·8	702·1
703·2	702·5	701·8	701·1	700·3	699·6
700·7	700·0	699·3	698·6	697·9	697·2
698·2	697·5	696·8	696·1	695·4	694·7
695·8	695·1	694·4	693·7	693·0	692·3
693·4	692·7	692·0	691·3	690·6	689·9
691·0	690·3	689·6	688·9	688·2	687·5
688·6	687·9	687·2	686·5	685·8	685·1
686·2	685·5	684·8	684·1	683·4	682·8
683·8	683·2	682·5	681·8	681·1	680·4
681·5	680·8	680·1	679·4	678·8	678·1
679·2	678·5	677·8	677·1	676·4	675·8
676·9	676·2	675·5	674·8	674·1	673·5

NITRATE OF

Weight of Assay in Milligrs.	0	1	2	3	4
1475	678·0	677·3	676·6	675·9	675·2
1480	675·7	675·0	674·3	673·6	673·0
1485	673·4	672·7	672·0	671·4	670·7
1490	671·1	670·5	669·8	669·1	668·5
1495	668·9	668·2	667·6	666·9	666·2
1500	666·7	666·0	665·3	664·7	664·0
1505	664·5	663·8	663·1	662·5	661·8
1510	662·3	661·6	660·9	660·3	659·6
1515	660·1	659·4	658·7	658·1	657·4
1520	657·9	657·2	656·6	655·9	655·3
1525	655·7	655·1	654·4	653·8	653·1
1530	653·6	652·9	652·3	651·6	651·0
1535	651·5	650·8	650·2	649·5	648·9
1540	649·4	648·7	648·0	647·4	646·7
1545	647·2	646·6	645·9	645·3	644·7
1550	645·2	644·5	643·9	643·2	642·6
1555	643·1	642·4	641·8	641·2	640·5
1560	641·0	640·4	639·7	639·1	638·5
1565	639·0	638·3	637·7	637·1	636·4
1570	636·9	636·3	635·7	635·0	634·4
1575	634·9	634·3	633·6	633·0	632·4
1580	632·9	632·3	631·6	631·0	630·4
1585	630·9	630·3	629·6	629·0	628·4
1590	628·9	628·3	627·7	627·0	626·4
1595	627·0	626·3	625·7	625·1	624·4
1600	625·0	624·4	623·7	923·1	622·5
1605	623·1	622·4	621·8	621·2	620·6
1610	621·1	620·5	619·9	619·2	618·6
1615	619·2	618·6	618·0	617·3	616·7
1620	617·3	616·7	616·0	615·4	614·8
1625	615·4	614·8	614·1	613·5	612·9
1630	613·5	612·9	612·3	611·7	611·0
1635	611·6	611·0	610·4	609·8	609·2

SILVER—*continued.*

5	6	7	8	9	10
674·6	673·9	673·2	672·5	671·9	671·2
672·3	671·6	670·9	670·3	669·6	668·9
670·0	669·4	668·7	668·0	667·3	666·7
667·8	667·1	666·4	665·8	665·1	664·4
665·5	664·9	664·2	663·5	662·9	662·2
663·3	662·7	662·0	661·3	660·7	660·0
661·1	660·5	659·8	659·1	658·5	657·8
658·9	658·3	657·6	656·9	656·3	655·6
656·8	656·1	655·4	654·8	654·1	653·5
654·6	653·9	653·3	652·6	652·0	651·3
652·5	651·8	651·1	650·5	649·8	649·2
650·3	649·7	649·0	648·4	647·7	647·1
648·2	647·6	646·9	646·2	645·6	644·9
646·1	645·4	644·8	644·2	643·5	642·9
644·0	643·4	642·7	642·1	641·4	640·8
641·9	641·3	640·6	640·0	639·3	638·7
639·9	639·3	638·6	637·9	637·3	636·7
637·8	637·2	636·5	635·9	635·3	634·6
635·8	635·1	634·5	633·9	633·2	632·6
633·8	633·1	632·5	631·8	631·2	630·6
631·7	631·1	630·5	629·8	629·2	628·6
629·7	629·1	628·5	627·8	627·2	626·6
627·8	627·1	626·5	625·9	625·2	624·6
625·8	625·2	624·5	623·9	623·3	622·6
623·8	623·2	622·6	621·9	621·3	620·7
621·9	621·2	620·6	620·0	619·4	618·7
619·9	619·3	618·7	618·1	617·4	616·1
618·0	617·4	616·8	616·1	615·5	614·9
616·1	615·5	614·9	614·2	613·6	613·0
614·2	613·6	613·0	612·3	611·7	611·1
612·3	611·7	611·1	610·5	609·8	609·2
610·4	609·8	609·2	608·6	608·0	607·4
608·6	607·9	607·3	606·7	606·1	605·5

NITRATE OF

Weight of Assay in Milligrs.	0	1	2	3	4
1640	609·8	609·1	608·5	607·9	607·3
1645	607·9	607·3	606·7	606·1	605·5
1650	606·1	605·4	604·8	604·2	603·6
1655	604·2	603·6	603·0	602·4	601·8
1660	602·4	601·8	601·2	600·6	600·0
1665	600·6	600·0	599·4	598·8	598·2
1670	598·8	598·2	597·6	597·0	596·4
1675	597·0	596·4	595·8	595·2	594·6
1680	595·2	594·6	594·0	593·4	592·9
1685	593·5	592·9	592·3	591·7	591·1
1690	591·7	591·1	590·5	589·9	589·3
1695	590·0	589·4	588·8	588·2	587·6
1700	588·2	587·6	587·1	586·5	585·9
1705	586·5	585·9	585·3	584·7	584·2
1710	584·8	584·2	583·6	583·0	582·5
1715	583·1	582·5	581·9	581·3	580·8
1720	581·4	580·8	580·2	579·6	579·1
1725	579·7	579·1	578·5	578·0	577·4
1730	578·0	577·5	576·9	576·3	575·7
1735	576·4	575·8	575·2	574·6	574·1
1740	574·7	574·1	573·6	573·0	572·4
1745	573·1	572·5	571·9	571·3	570·8
1750	571·4	570·9	570·3	569·7	569·1
1755	569·8	569·2	568·7	568·1	567·5
1760	568·2	567·6	567·0	566·5	565·9
1765	566·6	566·0	565·4	564·9	564·3
1770	565·0	564·4	563·8	563·3	562·7
1775	563·4	562·8	562·2	561·7	561·1
1780	561·8	561·2	560·7	560·1	559·5
1785	560·2	559·7	559·1	558·5	558·0
1790	558·7	558·1	557·5	557·0	556·4
1795	557·1	556·5	556·0	555·4	554·9
1800	555·6	555·5	554·4	553·9	553·3

SILVER—*continued.*

5	6	7	8	9	10
606·7	606·1	605·5	604·9	604·3	603·7
604·9	604·3	603·6	603·0	602·4	601·8
603·0	602·4	601·8	601·2	600·6	600·0
601·2	600·6	600·0	599·4	598·8	598·2
599·4	598·8	598·2	597·6	597·0	596·4
597·6	597·0	596·4	595·8	595·2	594·6
595·8	595·2	594·6	594·0	593·4	592·8
594·0	593·4	592·8	592·2	591·6	591·0
592·3	591·7	591·1	590·5	589·9	589·3
590·5	589·9	589·3	588·7	588·1	587·5
588·8	588·2	587·6	587·0	586·4	585·8
587·0	586·4	585·8	585·2	584·7	584·1
583·5	584·7	584·1	583·5	582·9	582·3
585·6	583·0	582·4	581·8	581·2	580·6
581·9	581·3	580·7	580·1	579·5	578·9
580·2	579·6	579·0	578·4	577·8	577·3
578·5	577·9	577·3	576·7	576·2	575·6
576·8	576·2	575·6	575·1	574·5	573·9
575·1	574·6	574·0	573·4	572·8	572·2
573·5	572·9	572·3	571·8	571·2	570·6
571·8	571·3	570·7	570·1	569·5	569·0
570·2	569·6	569·0	568·5	567·9	567·3
568·6	568·0	567·4	566·9	566·3	565·7
566·9	566·4	565·8	565·2	564·7	564·1
565·3	564·8	564·2	563·6	563·1	562·5
563·7	563·2	562·6	562·0	561·5	560·9
562·1	561·6	561·0	560·4	559·9	559·3
560·6	560·0	559·4	558·9	558·3	557·7
559·0	558·4	557·9	557·3	556·7	556·2
557·4	556·9	556·3	555·7	555·2	554·6
555·9	555·3	554·7	554·2	553·6	553·1
554·3	553·8	553·2	552·6	552·1	551·5
552·8	552·2	551·7	551·1	550·6	550·0

NITRATE OF

Weight of Assay in Milligrs.	0	1	2	3	4
1805	554·0	553·5	552·9	552·3	551·8
1810	552·5	551·9	551·4	550·8	550·3
1815	551·0	550·4	549·9	549·3	548·8
1820	549·4	548·9	548·3	547·8	547·2
1825	547·9	547·4	546·8	546·3	545·7
1830	546·4	545·9	545·4	544·8	544·3
1835	545·0	544·4	543·9	543·3	542·8
1840	543·5	542·9	542·4	541·8	541·3
1845	542·0	541·5	540·9	540·4	539·8
1850	540·5	540·0	539·5	538·9	538·4
1855	539·1	538·5	538·0	537·5	536·9
1860	537·6	537·1	536·6	536·0	535·5
1865	536·2	535·7	535·1	534·6	534·0
1870	534·8	534·2	533·7	533·2	532·6
1875	533·3	532·8	532·3	531·7	531·2
1880	531·9	531·4	530·8	530·3	529·8
1885	530·5	530·0	529·4	528·9	528·4
1890	529·1	528·6	528·0	527·5	527·0
1895	527·7	527·2	526·6	526·1	526·6
1900	526·3	525·8	525·3	524·7	524·2
1905	524·9	524·4	523·2	523·4	522·8
1910	523·6	523·0	522·5	522·0	521·5
1915	522·2	521·7	521·1	520·6	520·1
1920	520·8	520·3	519·8	519·3	518·7
1925	519·5	519·0	518·4	517·9	517·4
1930	518·1	517·6	517·1	516·6	516·1
1935	516·8	516·3	515·8	515·2	514·7
1940	515·5	514·9	514·4	513·9	513·4
1945	614·1	513·6	513·1	512·6	512·1
1950	512·8	512·3	511·8	511·3	510·8
1955	511·5	511·0	510·5	510·0	509·5
1960	510·2	509·7	509·2	508·7	508·2
1965	508·9	508·4	507·9	507·4	506·9

SILVER—*continued.*

5	6	7	8	9	10
551·2	550·7	550·1	549·6	549·0	548·5
549·7	549·2	548·6	548·1	547·5	547·0
548·2	547·7	547·1	546·6	546·0	545·5
546·7	546·2	545·6	545·1	544·5	544·0
545·2	544·7	544·1	543·6	543·0	542·5
542·7	543·2	542·6	542·1	541·5	541·0
542·2	541·7	541·1	540·6	540·0	539·5
540·8	540·2	539·7	539·1	538·6	538·0
539·3	538·7	538·2	537·7	537·1	536·6
537·8	537·3	536·8	536·2	535·7	535·1
536·4	535·8	535·3	534·8	534·2	533·7
534·9	534·4	533·9	533·3	532·8	532·3
533·5	533·0	532·4	531·9	531·4	530·8
532·1	531·5	531·0	530·5	529·9	529·4
530·7	530·1	529·6	529·1	528·5	528·0
529·3	528·7	528·2	527·7	527·1	526·6
527·8	527·3	526·8	526·3	525·7	525·2
526·5	525·9	525·4	524·9	524·3	523·8
525·1	524·5	524·0	523·5	523·0	522·4
523·7	523·2	522·6	522·1	521·6	521·0
522·3	521·8	521·3	520·7	520·2	519·7
520·9	520·4	519·9	519·4	518·8	518·3
519·6	519·1	518·5	518·0	517·5	517·0
518·2	517·7	517·2	516·7	516·1	515·6
516·9	516·4	515·8	515·3	514·8	514·3
515·5	515·0	514·5	514·0	513·5	512·9
514·2	513·7	513·2	512·7	512·1	511·6
512·9	512·4	511·9	511·3	510·0	510·3
511·6	511·0	510·5	510·0	509·5	509·0
510·3	509·7	509·2	508·7	508·2	507·7
508·9	508·4	507·9	507·4	506·9	506·4
507·6	507·1	506·6	506·1	505·6	505·1
506·4	505·8	505·3	504·8	504·3	503·8

NITRATE OF

Weight of Assay in Milligrs.	0	1	2	3	4
1970	507·6	507·1	506·6	506·1	505·7
1975	506·3	505·8	505·3	504·8	504·3
1980	505·0	504·5	504·0	503·5	503·0
1985	503·8	503·3	502·8	502·3	501·8
1990	502·5	502·0	501·5	501·0	500·5
1995	501·3	500·7	500·2	499·7	499·2
2000	500·0	499·5	499·0	498·5	498·0

TABLES FOR DETERMINING THE STANDARD OF ANY SILVER APPROXIMATELY CONTAINING

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1000	1000·0				
1005	995·0	996·0	997·0	998·0	999·0
1010	990·1	991·1	992·1	993·1	994·1
1015	985·2	986·2	987·2	988·2	989·1
1020	980·4	981·5	982·4	983·3	984·3
1025	975·6	976·6	977·6	978·5	979·5
1030	970·9	971·8	972·8	973·8	974·8
1035	966·2	967·1	968·1	969·1	970·0
1040	961·5	962·5	963·5	964·4	965·4
1045	956·9	957·9	958·8	959·8	960·8
1050	952·4	953·3	954·3	955·2	956·2
1055	947·9	948·8	949·8	950·7	951·7

SILVER—*continued.*

5	6	7	8	9	10
505·1	504·6	504·1	503·5	503·0	500·5
503·8	503·3	502·8	502·3	501·8	501·3
502·5	509·0	501·5	501·0	500·5	500·0
501·3	500·8	500·2	499·7	499·2	498·7
500·0	499·5	499·0	498·5	498·0	497·5
498·7	498·2	497·7	497·2	496·7	496·2
497·5	497·0	496·5	496·0	495·5	495·0

ALLOY BY EMPLOYING AN AMOUNT OF ALLOY ALWAYS THE SAME AMOUNT OF SILVER.

SALT.

5	6	7	8	9	10
1000·0					
995·0	996·0	997·0	998·0	999·0	1000·0
990·1	991·1	992·1	993·1	994·1	995·1
985·3	986·3	987·2	988·2	989·2	990·2
980·5	981·5	982·4	983·4	984·4	985·4
975·7	976·7	977·7	978·6	979·6	980·6
971·0	972·0	972·9	973·9	974·9	975·8
966·3	967·3	968·3	969·2	970·2	971·1
961·7	962·7	963·6	964·6	965·5	966·5
957·1	958·1	959·0	960·0	960·9	961·9
952·6	953·5	954·5	955·4	956·4	957·3

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1060	943·4	944·3	945·3	946·2	947·2
1065	939·9	939·9	940·8	941·8	942·7
1070	934·6	935·5	936·4	937·4	938·3
1075	930·2	931·2	932·1	933·0	933·9
1080	925·9	926·8	927·8	928·7	929·6
1085	921·7	922·6	923·5	924·4	925·3
1090	917·4	918·3	919·3	920·2	921·1
1095	913·2	914·2	915·1	916·0	917·0
1100	909·1	910·0	910·9	911·8	912·7
1105	905·0	905·9	906·8	907·7	908·6
1110	900·9	901·8	902·7	903·6	904·5
1115	896·9	897·8	898·6	899·5	900·4
1120	892·9	893·7	894·6	895.5	896·4
1125	888·9	889·8	890·7	891·6	892·4
1130	885·0	885·8	886·7	887·6	888·5
1135	881·1	881·9	882·8	883·7	884·6
1140	877·2	878·1	878·9	879·8	880·7
1145	873·4	874·2	875·1	876·0	876·9
1150	869·6	870·4	871·3	872·2	873·0
1155	865·8	866·7	867·4	868·4	869·3
1160	862·1	862·9	863·8	864·7	865·5
1165	858·4	859·2	860·1	860·9	861·8
1170	854·7	855 6	856·4	857·3	858·1
1175	851·1	851·9	852·8	853·6	854·5
1180	847·5	848·3	849·2	850·0	850·8
1185	843·9	844·7	845·6	846·4	847·3
1190	840·3	841·2	842·0	842·9	843·7
1195	836·8	837·7	838·5	839·3	840·2
1200	833·3	834·2	835·0	835·8	836·7
1205	829·9	830·7	831·5	832·4	833·2
1210	826·4	827·3	828·1	828·9	829·7
1215	823·0	823·9	824·7	825·5	826·3
1220	819·7	820·5	821·3	822·1	822·9

SALT—*continued.*

5	6	7	8	9	10
948·1	949·1	950.0	950·9	951·9	952·8
943·7	944·6	945·5	946·5	947·4	948·4
939·3	940·2	941·1	942·1	943·0	943·9
934·9	935·8	936·7	937·7	938·6	939·5
930·6	931·5	932·4	933·3	934·3	935·2
926·3	927·2	928·1	929·0	930·0	930·9
922·0	922·9	923·8	924.8	925·7	926·6
917·8	918·7	919·6	920·5	921·5	922·4
913·6	914·5	915·4	916·4	917·3	918·2
909·5	910·4	911·3	912·2	913·1	914·0
905·4	906·3	907·2	908·1	909·0	909·9
901·3	902·2	903·1	904·0	904·9	905.8
897·3	898·2	899·1	900·0	900·9	901·8
893·3	894·2	895·1	896·0	896·9	897·8
889·4	890·3	891·1	892·0	892·9	893·8
885·5	886·3	887·2	888.1	889·0	889·9
881·6	882·5	883·3	884·2	885·1	886·0
877·7	878·6	879·5	880·3	881·2	882·1
873·9	874·8	875·7	876·5	877·4	878·3
870·1	871·0	871·9	872·7	873·6	874·5
866·4	867·2	868·1	869·0	869·8	870·7
862·7	863·5	864·4	865·2	866·1	866·9
859·0	859·8	860·7	861·5	862·4	863·2
855·3	856·2	857·0	857·9	858·7	859·6
851·7	852·5	853·4	854·2	855·1	855·9
848·1	848·9	849·8	850·6	851·5	852·3
844·5	845·4	846·2	847·1	847·9	848·7
841·0	841·8	842·7	843·5	844·3	845·2
837·5	838·3	839·2	840·0	840·8	841·7
834·0	834·8	835·7	836.5	837·3	838·2
830·6	831·4	832·2	833·1	833·9	834·7
827·2	828·0	828·8	829·6	830·4	831·3
823·8	824·6	825·4	826·2	827·0	827·9

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1225	816·3	817·1	818·0	818·8	819·6
1230	813·0	813·8	814·6	815·4	816·3
1235	809·7	810·5	811·3	812·1	813·0
1240	806·5	807·3	808·1	808·9	809·7
1245	803·2	804·0	804·8	805·6	806·4
1250	800·0	800·8	801·6	802·4	803·2
1255	796·8	797·6	798·4	799·2	800·0
1260	793·6	794·4	795·2	796·0	796·8
1265	790·5	791·3	792·1	792·9	793·7
1270	787·4	788·2	789·0	789·8	790·5
1275	784·3	785·1	785·9	786·7	787·4
1280	781·2	782·0	782·8	783·6	784·4
1285	778·2	779·0	779·8	780·5	781·3
1290	775·2	776·0	776·7	777·5	778·3
1295	772·2	773·0	773·7	774·5	775·3
1300	769·2	770·0	770·8	771·5	772·3
1305	766·3	767·0	767·8	768·6	769·3
1310	763·4	764·1	764·9	765·6	766·4
1315	760·5	761·2	762·0	762·7	763·5
1320	757·6	758·3	759·1	759·8	760·6
1325	754·7	755·5	756·2	757·0	757·7
1330	751·9	752·6	753·4	754·1	754·9
1335	749·1	749·8	750·6	751·3	752·1
1340	746·3	747·0	747·8	748·5	749·2
1345	743·5	744·2	745·0	745·7	746·5
1350	740·7	741·5	742·2	743·0	743·7
1355	738·0	738·7	739·5	740·2	741·0
1360	735·3	736·0	736·8	737·5	738·2
1365	732·6	733·3	734·1	734·8	735·5
1370	729·9	730·7	731·4	732·1	732·8
1375	727·3	728·0	728·7	729·4	730·2
1380	724·6	725·4	726·1	726·8	727·5
1385	722·0	722·7	723·5	724·2	724·9

SALT—*continued.*

5	6	7	8	9	10
820·4	821·2	822·0	822·9	823·7	824·5
817·1	817·9	818·7	819·5	820·3	821·1
813·8	814·6	815·4	816·2	817·0	817·8
810·5	811·3	812·1	812·9	813·7	814·5
807·2	808·0	808·8	809·6	810·4	811·2
804·0	804·8	805·6	806·4	807·2	808·0
800·8	801·6	802·4	803·2	804·0	804·8
797·6	798·4	799·2	800·0	800·8	801·6
794·5	795·3	796·0	796·8	797·6	798·4
791·3	792·1	792·9	793·7	794·5	795·3
788·2	789·0	789·8	790·6	791·4	792·2
785·2	786·0	786·7	787·5	788·3	789·1
782·1	782·9	783·7	784·4	785·2	786·0
779·1	779·8	780·6	781·4	782·2	782·9
776·1	776·8	777·6	778·4	779·1	779·9
773·1	773·8	774·6	775·4	776·1	776·9
770·1	770·9	771·6	772·4	773·2	773·9
767·2	767·9	768·7	769·5	770·2	771·0
764·3	765·0	765·8	766·5	767·3	768·1
761·4	762·1	762·9	763·6	764·4	765·2
758·5	759·2	760·0	760·7	761·5	762·3
755·6	756·4	757·1	757·9	758·6	759·4
752·8	753·6	754·3	755·1	755·8	756·6
750·0	750·7	751·5	752·2	753·0	753·7
747·2	748·0	748·7	749·4	750·2	750·9
744·4	745·2	745·9	746·7	747·4	748·1
741·7	742·4	743·2	743·9	744·6	745·4
739·0	739·7	740·4	741·2	741·9	742·6
736·3	737·0	737·7	738·5	739·2	739·9
733·6	734·3	735·0	735·8	736·5	737·2
730·9	731·6	732·4	733·2	733·8	734·5
728·3	729·0	729·7	730·4	731·2	731·9
725·6	726·3	727·1	727·8	728·5	729·2

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1390	719·4	720·1	720·9	721·6	722·3
1395	716·8	717·6	718·3	719·0	719·7
1400	714·3	715·0	715·7	7164·	717·1
1405	711·7	712·5	713·2	713·9	714·6
1410	709·2	709·9	710·6	711·3	712·1
1415	706·7	707·4	708·1	708·8	709·5
1420	704·2	704·9	705·6	706·3	707·0
1425	701·8	702·5	703·2	703·9	704·6
1430	699·3	700·0	700·7	701·4	702·1
1435	696·9	697·6	698·3	698·9	699·6
1440	694·4	695·1	695·8	696·5	697·2
1445	692·0	692·7	693·4	694·1	694·8
1450	689·7	690·3	691·0	691·7	692·4
1455	687·3	688·0	688·7	689·3	690·0
1460	684·9	685·6	686·3	687·0	687·7
1465	682·6	683·3	684·0	684·6	685·3
1470	680·3	680·9	681·6	682·3	683·0
1475	678·0	678·6	679·3	680·0	680·7
1480	675·7	676·3	677·0	677·7	678·4
1485	673·4	674·1	674·7	675·4	676·1
1490	671·1	671·8	672·5	673·1	673·8
1495	668·9	669·6	670·2	670·9	671·6
1500	666·7	667·3	668·0	668·7	669·3
1505	664·5	665·1	665·8	666·4	667·1
1510	662·3	662·9	663·6	664·2	664·9
1515	660·1	660·7	661·4	662·0	662·7
1520	657·9	658·5	659·2	659·9	660·5
1525	655·7	656·4	657·0	657·7	658·4
1530	653·6	654·2	654·9	655·6	656·2
1535	651·5	652·1	652·8	653·4	654·1
1540	649·4	650·0	650·6	651·3	651·9
1545	647·2	647·9	648·5	649·2	649·8
1550	645·2	645·8	646·4	647·1	647·7

SALT—*continued.*

5	6	7	8	9	10
723·0	723·7	724·5	725·2	725·9	726·6
720·4	721·1	721·9	722·6	723·3	724·0
717·9	718·6	719·3	720·0	720·7	721·4
715·3	716·0	716·7	717·4	718·1	718·9
712·8	713·5	714·2	714·9	715·6	716·3
710·2	710·9	711·7	712·4	713·1	713·8
707·7	708·4	709·2	709·9	710·6	711·3
705·3	706·0	706·7	707·4	708·1	708·8
702·8	703·5	704·2	704·9	705·6	706·3
700·3	701·0	701·7	702·4	703·1	703·8
697·9	698·6	699·3	700·0	700·7	701·4
695·5	696·2	696·9	697·6	698·3	699·0
693·1	693·8	694·5	695·2	695·9	696·6
690·7	691·4	692·1	692·8	693·5	694·2
688·4	689·0	689·7	690·4	691·1	691·8
686·0	686·7	687·4	688·0	688·7	689·4
683·7	684·3	685·0	685·7	686·4	687·1
681·4	682·0	682·7	683·4	684·1	684·7
679·1	679·7	680·4	681·1	681·8	682·4
676·8	677·4	678·1	678·8	679·5	680·1
674·5	675·2	675·8	676·5	677·2	677·8
672·2	672·9	673·6	674·2	674·9	675·6
670·0	670·7	671·3	672·0	672·7	673·3
667·8	668·4	669·1	669·8	670·4	671·1
665·6	666·2	666·9	667·5	668·2	668·7
663·4	664·0	664·7	665·3	666·0	666·7
661·2	661·8	662·5	663·2	663·8	664·5
659·0	659·7	660·3	661·0	661·6	662·3
656·9	657·5	658·2	658·8	659·5	660·1
654·7	655·4	656·0	656·7	657·3	658·0
652·6	653·2	653·9	654·5	655·2	655·8
650·5	651·1	651·8	652·4	653·1	653·7
648·4	649·0	649·7	650·3	651·0	651·6

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1555	643·1	643·7	644·4	645·0	645·7
1560	641·0	641·7	642·3	642·9	643·6
1565	639·0	639·6	640·3	640·9	641·5
1570	636·9	637·6	638·2	638·8	639·5
1575	634·9	635·6	636·2	636·8	637·5
1580	632·9	633·5	634·2	634·8	635·4
1585	630·9	631·5	632·2	632·8	633·4
1590	628·9	629·6	630·2	630·8	631·4
1595	627·0	627·6	628·2	628·8	629·5
1600	625·0	625·6	626·2	626·9	627·5
1605	623·1	623·7	624·3	624·9	625·5
1610	621·1	621·7	622·4	623·0	623·6
1615	619·2	619·8	620·4	621·0	621·7
1620	617·3	617·9	618·5	619·1	619·7
1625	615·4	616·0	616·6	617·2	617·8
1630	613·5	614·1	614·7	615·3	615·9
1635	611·6	612·2	612·8	613·5	614·1
1640	609·8	610·4	611·0	611·6	612·2
1645	607·9	608·5	609·1	609·7	610·3
1650	606·1	606·7	607·3	607·9	608·5
1655	604·2	604·8	605·4	606·0	606·6
1660	602·4	603·0	603·6	604·2	604·8
1665	600·6	601·2	601·8	602·4	603·0
1670	598·8	599·4	600·0	600·6	601·2
1675	597·0	597·6	598·2	598·8	599·4
1680	595·2	595·8	596·4	597·0	597·6
1685	593·5	594·1	594·7	595·2	595·8
1690	591·7	592·3	592·9	593·5	594·1
1695	590·0	590·6	591·1	591·7	592·3
1700	588·2	588·8	589·4	590·0	590·6
1705	586·5	587·1	587·7	588·3	588·9
1710	584·8	585·4	586·0	586·5	587·1
1715	583·1	583·7	584·3	584·8	585·4

SALT—*continued.*

5	6	7	8	9	10
646·3	646·9	647·6	648·2	648·9	649·5
644·2	644·9	645·5	646·1	646·8	647·4
642·2	642·8	643·4	644·1	644·7	645·4
640·1	640·8	641·4	642·0	642·7	643·3
638·1	638·7	639·4	640·0	640·6	641·3
636·1	636·7	637·3	638·0	638·6	639·2
634·1	634·7	635·3	636·0	636·6	637·2
632·1	632·7	633·3	634·0	634·6	635·2
630·1	630·7	631·3	632·0	632·6	633·2
628·1	628·7	629·4	630·0	630·6	631·2
626·2	626·8	627·4	628·0	628·7	629·3
624·2	624·8	625·5	626·1	626·7	627·3
622·3	622·9	623·5	624·1	624·8	625·4
620·4	621·0	621·6	622·2	622·8	623.5
618·5	619·1	619·7	620·3	620·9	621·5
616·6	617·2	617·8	618·4	619·0	619·6
614·7	615·3	615·9	616·5	617·1	617·7
612·8	613·4	614·0	614·6	615·2	615·8
610·9	611·5	612·2	612·8	613·4	614·0
609·1	609·7	610·3	610·9	611·5	612·1
607·2	607·8	608·5	609·1	609·7	610·3
605·4	606·0	606·6	607·2	607·8	608·4
603·6	604·2	604·8	605·4	606·0	606·6
601·8	602·4	603·0	603·6	604·2	604·8
600·0	600·6	601·2	601·8	602·4	603·0
598·2	598·8	599·4	600·0	600·6	601·2
596·4	597·0	597·6	598·2	598·9	599·4
594·7	595·3	595·9	596·4	597·0	597·6
592·9	593·5	594·1	594·7	595·3	595·9
591·2	591·8	592·3	592·9	593·5	594·1
589·4	590·0	590·6	591·2	591·8	592·4
587·7	588·3	588·9	589·5	590·1	590·6
586·0	586·6	587·2	587·8	588·3	588·9

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1720	581·4	582·0	582·6	583·1	583·7
1725	579·7	580·3	580·9	581·4	582·0
1730	578·0	578·6	579·2	579·8	580·3
1735	576·4	576·9	577·5	578·1	578·7
1740	574·7	575·3	575·9	576·4	577·0
1745	573·1	573·6	574·2	574·8	575·4
1750	571·4	572·0	572·6	573·1	573·7
1755	569·8	570·4	570·9	571·5	572·1
1760	568·2	568·7	569·3	569·9	570·4
1765	566·6	567·1	567·7	568·3	568·8
1770	565·0	565·5	566·1	566·7	567·2
1775	563·4	563·9	564·5	565·1	565·6
1780	561·8	562·4	562·9	563·5	564·0
1785	560·2	560·8	561·3	561·9	562·5
1790	558·7	559·2	559·8	560·3	560·9
1795	557·1	557·7	558·2	558·8	559·3
1800	555·6	556·1	556·7	557·2	557·8
1805	554·0	554·6	555·1	555·7	556·2
1810	552·5	553·0	553·6	554·1	554·7
1815	551·0	551·5	552·1	552·6	553·2
1820	549·4	550·0	550·5	551·1	551·6
1825	547·9	548·5	549·0	549·6	550·1
1830	546·4	547·0	547·5	548·1	548·6
1835	545·0	545·5	546·0	546·6	547·1
1840	543·5	544·0	544·6	545·1	545·6
1845	542·0	542·5	543·1	543·6	544·2
1850	540·5	541·1	541·6	542·2	542·7
1855	539·1	539·6	540·2	540·7	541·2
1860	537·6	538·2	538·7	539·2	539·8
1865	536·2	536·7	537·3	537·8	538·3
1870	534·8	535·3	535·8	536·4	536·9
1875	533·3	533·9	534·4	534·9	535·5
1880	531·9	532·4	533·0	533·5	534·0

SALT—*continued.*

5	6	7	8	9	10
584·3	584·9	585·5	586·0	586·6	587·2
582·6	583·2	583·8	584·3	584·9	585·5
580·9	581·5	582·1	582·7	583·2	583·8
579·2	579·8	580·4	581·0	581·6	582·1
577·6	578·2	578·7	579·3	579·9	580·5
575·9	576·5	577·1	577·6	578·2	578·8
574·3	574·9	575·4	576·0	576·6	577·1
572·6	573·2	573·8	574·4	574·9	575·5
571·0	571·6	572·2	572·7	573·3	573·9
569·4	570·0	570·5	571·1	571·7	572·2
567·8	568·4	568·9	569·5	570·1	570·6
566·2	566·8	567·3	567·9	568·4	569·0
564·6	565·2	565·7	566·3	566·8	567·4
563·0	563·6	564·1	564·7	565·3	565·8
561·4	562·0	562·6	563·1	563·7	564·2
559·9	560·4	561·0	561·6	562·1	562·7
558·3	558·9	559·4	560·0	560·6	561·1
556·8	557·3	557·9	558·4	559·0	559·6
555·2	555·8	556·3	556·9	557·5	558·0
553·7	554·3	554·8	555·4	555·9	556·5
552·2	552·7	553·3	553·8	554·4	554·9
550·7	551·2	551·8	552·3	552·9	553·4
549·2	549·7	550·3	550·8	551·4	551·9
547·7	548·2	548·8	549·3	549·9	550·4
546·2	546·7	547·3	547·8	548·4	548·9
544·7	545·3	545·8	546·3	546·9	547·4
543·2	543·8	544·3	544·9	545·4	545·9
541·8	542·3	542·9	543·4	543·9	544·5
540·3	540·9	541·4	541·9	542·5	543·0
538·9	539·4	539·9	540·5	541·0	541·5
537·4	538·0	538·5	539·0	539·6	540·1
536·0	536·5	537·1	537·6	538·1	538·7
534·6	535·1	535·6	536·2	536·7	537·2

COMMON

Weight of Assay in Milligrs.	0	1	2	3	4
1885	530·5	531·0	531·6	532·1	532·6
1890	529·1	529·6	530·2	530·7	531·2
1895	527·7	528·2	528·8	529·3	529·8
1900	526·3	526·8	527·4	527·9	528·4
1905	524·9	525·4	526·0	526·5	527·0
1910	523·6	524·1	524·6	525·1	525·6
1915	522·2	522·7	523·2	523·8	524·3
1920	520·8	521·3	521·9	522·4	522·9
1925	519·5	520·0	520·5	521·0	521·6
1930	518·1	518·6	519·2	519·7	520·2
1935	516·8	517·3	517·8	518·3	518·9
1940	515·5	516·0	516·5	517·0	517·5
1945	514·1	514·6	515·2	515·7	516·2
1950	512·8	513·3	513·8	514·4	514·9
1955	511·5	512·0	512·5	513·0	513·5
1960	510·2	510·7	511·2	511·7	512·2
1965	508·9	509·4	509·9	510·4	510·9
1970	507·6	508·1	508·6	509·1	509·6
1975	506·3	506·8	507·3	507·8	508·3
1980	505·0	505·6	506·1	506·6	507·1
1985	503·8	504·3	504·8	505·3	505·8
1990	502·5	503·0	503·5	504·0	504·5
1995	501·3	501·8	502·3	502·8	503·3
2000	500·0	500·5	501·0	501·5	502·0

SALT—*continued.*

5	6	7	8	9	10
533·2	533·7	534·2	534·7	535·3	535·8
531·7	532·3	532·8	533·3	533·9	534·4
530·3	530·9	531·4	531·9	532·4	533·0
528·9	529·5	530·0	530·5	531·0	531·6
527·6	528·1	528·6	529·1	529·7	530·2
526·2	526·7	527·2	527·7	528·3	528·8
524·8	525·3	525·8	526·4	526·9	527·4
523·4	524·0	524·5	525·0	525·5	526·0
522·1	522·6	523·1	523·6	524·2	524·7
520·7	521·2	521·8	522·3	522·8	523·3
519·4	519·9	520·4	520·9	521·4	522·0
518·0	518·6	519·1	519·6	520·1	520·6
516·7	517·2	517·7	518·2	518·8	519·3
515·4	515·9	516·4	516·9	517·4	517·9
514·1	514·6	515·1	515·6	516·1	516·6
512·8	513·3	513·8	514·3	514·8	515·3
511·4	512·0	512·5	513·0	513·5	514·0
510·1	510·7	511·2	511·7	512·2	512·7
508·9	509·4	509·9	510·4	510·9	511·4
507·6	508·1	508·6	509·1	509·6	510·1
506·3	506·8	507·3	507·8	508·3	508·8
505·0	505·5	506·0	506.5	507·0	507·5
503·8	504·3	504·8	505·3	505·8	506·3
502·5	503·0	503·5	504·0	504·5	505·0

ASSAY TABLE, SHOWING THE AMOUNT OF GOLD OR SILVER, IN OUNCES, PENNYWEIGHTS, AND GRAINS, CONTAINED IN A TON OF ORE, &C., FROM THE WEIGHT OF METAL OBTAINED IN AN ASSAY OF 200 GRAINS OF MINERAL.

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·001	0	3	6	·028	4	11	11
·002	0	6	12	·029	4	14	17
·003	0	9	19	·030	4	18	0
·004	0	13	1	·031	5	1	6
·005	0	16	8	·032	5	4	12
·006	0	19	14	·033	5	7	19
·007	1	2	20	·034	5	11	1
·008	1	6	3	·035	5	14	8
·009	1	9	9	·036	5	17	14
·010	1	12	6	·037	6	0	20
·011	1	15	22	·038	6	4	3
·012	1	19	4	·039	6	7	9
·013	2	2	11	·040	6	10	16
·014	2	5	17	·041	6	13	22
·015	2	9	0	·042	6	17	4
·016	2	12	6	·043	7	0	11
·017	2	15	12	·044	7	3	17
·018	2	18	19	·045	7	7	0
·019	3	2	1	·046	7	10	6
·020	3	5	8	·047	7	13	12
·021	3	8	14	·048	7	16	19
·022	3	11	20	·049	8	0	1
·023	3	15	3	·050	8	3	8
.024	3	18	9	·051	8	6	14
·025	4	1	16	·052	8	9	20
·026	4	4	22	·053	8	13	3
·027	4	8	4	·054	8	16	9

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.	Gr.	Oz.	Dwts.	Grs.
·055	8	19	16	·091	14	17	6
·056	9	2	22	·092	15	0	12
·057	9	6	4	·093	15	3	19
·058	9	9	11	·094	15	7	1
·059	9	12	17	·095	15	10	8
·060	9	16	0	·096	15	13	14
·061	9	19	6	·097	15	16	20
·062	10	2	12	·098	16	0	3
·063	10	5	19	·099	16	3	9
·064	10	9	1	·100	16	6	16
·065	10	12	8	·101	16	9	22
·066	10	15	14	·102	16	13	4
·067	10	18	20	·103	16	16	11
·068	11	2	3	·104	16	19	17
·069	11	5	9	·105	17	3	0
·070	11	8	16	·106	17	6	6
·071	11	11	22	·107	17	9	12
·072	11	15	4	·108	17	12	19
·073	11	18	11	·109	17	16	1
·074	12	1	17	·110	17	19	8
·075	12	5	0	·111	18	2	14
·076	12	8	6	·112	18	5	20
·077	12	11	12	·113	18	9	3
·078	12	14	19	·114	18	12	9
·079	12	18	1	·115	18	15	16
·080	13	1	8	·116	18	18	22
·081	13	4	14	·117	19	2	4
·082	13	7	20	·118	19	5	11
·083	13	11	3	·119	19	8	17
·084	13	14	9	·120	19	12	0
·085	13	17	16	·121	19	15	6
·086	14	0	22	·122	19	18	12
·087	14	4	4	·123	20	1	19
·088	14	7	11	·124	20	5	1
·089	14	10	17	·125	20	8	8
·090	14	14	0	·126	20	11	14

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.	Gr.	Oz.	Dwts.	Grs.
·127	20	14	20	·163	26	12	11
·128	20	18	3	·164	26	15	17
·129	21	1	9	·165	26	19	0
·130	21	4	16	·166	27	2	6
·131	21	7	22	·167	27	5	12
·132	21	11	4	·168	27	8	19
·133	21	14	11	·169	27	12	1
·134	21	17	17	·170	27	15	8
·135	22	1	0	·171	27	18	14
·136	22	4	6	·172	28	1	20
·137	22	7	12	·173	28	5	3
·138	22	10	19	·174	28	8	9
·139	22	14	1	·175	28	11	16
·140	22	17	8	·176	28	14	22
·141	23	0	14	·177	28	18	4
·142	23	3	20	·178	29	1	11
·143	23	7	3	·179	29	4	17
·144	23	10	9	·180	29	8	0
·145	23	13	16	·181	29	11	6
·146	23	16	22	·182	29	14	12
·147	24	0	4	·183	29	17	19
·148	24	3	11	·184	30	1	1
·149	24	6	17	·185	30	4	8
·150	24	10	0	·186	30	7	14
·151	24	13	6	·187	30	10	20
·152	24	16	12	·188	30	14	3
·153	24	19	19	·189	30	17	9
·154	25	3	1	·190	31	0	16
·155	25	6	8	·191	31	3	22
·156	25	9	14	·192	31	7	4
·157	25	12	20	·193	31	10	11
·158	25	16	3	194	31	13	17
·159	25	19	9	·195	31	17	0
·160	26	2	16	·196	32	0	6
·161	26	5	22	·197	32	3	12
·162	26	9	4	·198	32	6	19

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.	Gr.	Oz.	Dwts.	Grs.
·199	32	10	1	·235	38	7	16
·200	32	13	8	·236	38	10	22
·201	32	16	14	·237	38	14	4
·202	32	19	20	·238	38	17	11
·203	33	3	3	·239	39	0	17
·204	33	6	9	·240	39	4	0
·205	33	9	16	·241	39	7	6
·206	33	12	22	·242	39	10	12
·207	33	16	4	·243	39	13	18
·208	33	19	11	·244	39	17	1
·209	34	2	17	·245	40	0	8
·210	34	6	0	·246	40	3	14
·211	34	9	6	·247	40	6	20
·212	34	12	12	·248	40	10	3
·213	34	15	19	·249	40	13	9
·214	34	19	1	·250	40	16	16
·215	35	2	8	·251	40	19	22
·216	35	5	14	·252	41	3	4
·217	35	8	20	·253	41	6	11
·218	35	12	3	·254	41	9	17
·219	35	15	9	·255	41	13	0
·220	35	18	16	·256	41	16	6
·221	36	1	22	·257	41	19	12
·222	36	5	4	·258	42	2	19
·223	36	8	11	·259	42	6	1
·224	36	11	17	·260	42	9	8
·225	36	15	0	·261	42	12	14
·226	36	18	6	·262	42	15	20
·227	37	1	12	·263	42	19	3
·228	37	4	19	·264	43	2	9
·229	37	8	1	·265	43	5	16
·230	37	11	8	·266	43	8	22
·231	37	14	14	·267	43	12	4
·232	37	17	20	·268	43	15	11
·233	38	1	3	·269	43	18	17
·234	38	4	9	·270	44	2	0

If 200 Grains of Ore give of FINE METAL Gr.	One Ton of Ore will yield of FINE METAL Oz.	Dwts.	Grs.	If 200 Grains of Ore give of FINE METAL Gr.	One Ton of Ore will yield of FINE METAL Oz.	Dwts.	Grs.
·271	44	5	6	·307	50	2	20
·272	44	8	12	·308	50	6	3
·273	44	11	19	·309	50	9	9
·274	44	15	1	·310	50	12	16
·275	44	18	8	·311	50	15	22
·276	45	1	14	·312	50	19	4
·277	45	4	20	·313	51	2	11
·278	45	8	3	·314	51	5	17
·279	45	11	9	·315	51	9	0
·280	45	14	16	·316	51	12	6
·281	45	17	22	·317	51	15	12
·282	46	1	4	·318	51	18	19
·283	46	4	11	·319	52	2	1
·284	46	7	17	·320	52	5	8
·285	46	11	0	·321	52	8	14
·286	46	14	6	·322	52	11	20
·287	46	17	12	·323	52	15	3
·288	47	0	19	·324	52	18	9
·289	47	4	1	·325	53	1	16
·290	47	7	8	·326	53	4	22
·291	47	10	14	·327	53	8	4
·292	47	13	20	·328	53	11	11
·293	47	17	3	·329	53	14	17
·294	48	0	9	·330	53	18	0
·295	48	3	16	·331	54	1	6
·296	48	6	22	·332	54	4	12
·297	48	10	4	·333	54	7	19
·298	48	13	11	·334	54	11	1
·299	48	16	17	·335	54	14	8
·300	49	0	0	·336	54	17	14
·301	49	3	6	·337	55	0	20
·302	49	6	12	·338	55	4	3
·303	49	9	19	·339	55	7	9
·304	49	13	1	·340	55	10	16
·305	49	16	8	·341	55	13	22
·306	49	19	14	·342	55	17	4

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·343	56	0	11	·379	61	18	1
·344	56	3	17	·380	62	1	8
·345	56	7	0	·381	62	4	14
·346	56	10	6	·382	62	7	20
·347	56	13	12	·383	62	11	3
·348	56	16	19	·384	62	14	9
·349	57	0	1	·385	62	17	16
·350	57	3	8	·386	63	0	22
·351	57	6	14	·387	63	4	4
·352	57	9	20	·388	63	7	11
·353	57	13	3	·389	63	10	17
·354	57	16	9	·390	63	14	0
·355	57	19	16	·391	63	17	6
·356	58	2	22	·392	64	0	12
·357	58	6	4	·393	64	3	19
·358	58	9	11	·394	64	7	1
·359	58	12	17	·395	64	10	8
·360	58	16	0	·396	64	13	14
·361	58	19	6	·397	64	16	20
·362	59	9	12	·398	65	0	3
·363	59	5	19	·399	65	3	9
·364	59	9	1	·400	65	6	16
·365	59	12	8	·401	65	9	22
·366	59	15	14	·402	65	13	4
·367	59	18	20	·403	65	16	11
·368	60	2	3	·404	65	19	17
·369	60	5	9	·405	66	3	0
·370	60	8	16	·406	66	6	6
·371	60	11	22	·407	66	9	12
·372	60	15	4	·408	66	12	19
·373	60	18	11	·409	66	16	1
·374	61	1	17	·410	66	19	8
·375	61	5	0	·411	67	2	14
·376	61	8	6	·412	67	5	20
·377	61	11	12	·413	67	9	3
·378	61	14	19	·414	67	12	9

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·415	67	15	16	·451	73	13	6
·416	67	18	22	·452	73	16	12
·417	68	2	4	·453	73	19	19
·418	68	5	11	·454	74	3	1
·419	68	8	17	·455	74	6	8
·420	68	12	0	·456	74	9	14
·421	68	15	6	·457	74	12	20
·422	68	18	12	·458	74	16	3
·423	69	1	19	·459	74	19	9
·424	69	5	1	·460	75	2	16
·425	69	8	8	·461	75	5	22
·426	69	11	14	·462	75	9	4
·427	69	14	20	·463	75	12	11
·428	69	18	3	·464	75	15	17
·429	70	1	9	·465	75	19	0
·430	70	4	16	·466	76	2	6
·431	70	7	22	·467	76	5	12
·432	70	11	4	·468	76	8	19
·433	70	14	11	·469	76	12	1
·434	70	17	17	·470	76	15	8
·435	71	1	0	·471	76	18	14
·436	71	4	6	·472	77	1	20
·437	71	7	12	·473	77	5	3
·438	71	10	19	·474	77	8	9
·439	71	14	1	·475	77	11	16
·440	71	17	8	·476	77	14	22
·441	72	0	14	·477	77	18	4
·442	72	3	20	·478	78	1	11
·443	72	7	3	·479	78	4	17
·444	72	10	9	·480	78	8	0
·445	72	13	16	·481	78	11	6
·446	72	16	22	·482	78	14	12
·447	73	0	4	·483	78	17	19
·448	73	3	11	·484	79	1	1
·449	73	6	17	·485	79	4	8
·450	73	10	0	·486	79	7	14

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.	Gr.	Oz.	Dwts.	Grs.
·487	79	10	20	·523	85	8	11
·488	79	14	3	·524	85	11	17
·489	79	17	9	·525	85	15	0
·490	80	0	16	·526	85	18	6
·491	80	3	22	·527	86	1	12
·492	80	7	4	·528	86	4	19
·493	80	10	11	·529	86	8	1
·494	80	13	17	·530	86	11	8
·495	80	17	0	·531	86	14	14
·496	81	0	6	·532	86	17	20
·497	81	3	12	·533	87	1	3
·498	81	6	19	·534	87	4	9
·499	81	10	1	·535	87	7	16
·500	81	13	8	·536	87	10	22
·501	81	16	14	·537	87	14	4
·502	81	19	20	·538	87	17	11
·503	82	3	3	·539	88	0	17
·504	82	6	9	·540	88	4	0
·505	82	9	16	·541	88	7	6
·506	82	12	22	·542	88	10	12
·507	82	16	4	·543	88	13	19
·508	82	19	11	·544	88	17	1
·509	83	2	17	·545	89	0	8
·510	83	6	0	·546	89	3	14
·511	83	9	6	·547	89	6	20
·512	83	12	12	·548	89	10	3
·513	83	15	19	·549	89	13	9
·514	83	19	1	·550	89	16	16
·515	84	2	8	·551	89	19	22
·516	84	5	14	·552	90	3	4
·517	84	8	20	·553	90	6	11
·518	84	12	3	·554	90	9	17
·519	84	15	9	·555	90	13	0
·520	84	18	16	·556	90	16	6
·521	85	1	22	·557	90	19	12
·522	85	5	4	·558	91	2	19

If 200 Grains of Ore give of FINE METAL Gr.	One Ton of Ore will yield of FINE METAL Oz.	Dwts.	Grs.	If 200 Grains of Ore give of FINE METAL Gr.	One Ton of Ore will yield of FINE METAL Oz.	Dwts.	Grs.
·559	91	6	1	·595	97	3	16
·560	91	9	8	·596	97	6	22
·561	91	12	14	·597	97	10	4
·562	91	15	20	·598	97	13	11
·563	91	19	3	·599	97	16	17
·564	92	2	9	·600	98	0	0
·565	92	5	16	·601	98	3	6
·566	92	8	22	·602	98	6	12
·567	92	12	4	·603	98	9	19
·568	92	15	11	·604	98	13	1
·569	92	18	17	·605	98	16	8
·570	93	2	0	·606	98	19	14
·571	93	5	6	·607	99	2	20
·572	93	8	12	·608	99	6	3
·573	93	11	19	·609	99	9	9
·574	93	15	1	·610	99	12	16
·575	93	18	8	·611	99	15	22
·576	94	1	14	·612	99	19	4
·577	94	4	20	·613	100	2	11
·578	94	8	3	·614	100	5	17
·579	94	11	9	·615	100	9	0
·580	94	14	16	·616	100	12	6
·581	94	17	22	·617	100	15	12
·582	95	1	4	·618	100	18	19
·583	95	4	11	·619	101	2	1
·584	95	7	17	·620	101	5	8
·585	95	11	0	·621	101	8	14
·586	95	14	6	·622	101	11	20
·587	95	17	12	·623	101	15	3
·588	96	0	19	·624	101	18	9
·589	96	4	1	·625	102	1	16
·590	96	7	8	·626	102	4	22
·591	96	10	14	·627	102	8	4
·592	96	13	20	·628	102	11	11
·593	96	17	3	·629	102	14	17
·594	97	0	9	·630	102	18	0

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·631	103	1	6	·667	108	18	20
·632	103	4	12	·668	109	2	3
·633	103	7	19	·669	109	5	9
·634	103	11	1	·670	109	8	16
·635	103	14	8	·671	109	11	22
·636	103	17	14	·672	109	15	4
·637	104	0	20	·673	109	18	11
·638	104	4	3	·674	110	1	17
·639	104	7	9	·675	110	5	0
·640	104	10	16	·676	110	8	6
·641	104	13	22	·677	110	11	12
·642	104	17	4	·678	110	14	19
·643	105	0	11	·679	110	18	1
·644	105	3	17	·680	111	1	8
·645	105	7	0	·681	111	4	14
·646	105	10	6	·682	111	7	20
·647	105	13	12	·683	111	11	3
·648	105	16	19	·684	111	14	9
·649	106	0	1	·685	111	17	6
·650	106	3	8	·686	112	0	22
·651	106	6	14	687	112	4	4
·652	106	9	20	·688	112	7	11
·653	106	13	3	·689	112	10	17
·654	106	16	9	·690	112	14	0
·655	106	19	16	·691	112	17	6
·656	107	2	22	·692	113	0	12
·657	107	6	4	·693	113	3	19
·658	107	9	11	·694	113	7	1
·659	107	12	17	·695	113	10	8
·660	107	16	0	·696	113	13	14
·661	107	19	6	·697	113	16	20
·662	108	2	12	·698	114	0	3
·663	108	5	19	·699	114	3	9
·664	108	9	1	·700	114	6	16
·665	108	12	8	·701	114	9	22
·666	108	15	14	·702	114	13	4

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·703	114	16	12	·739	120	14	1
·704	114	19	17	·740	120	17	2
·705	115	3	0	·741	121	0	14
·706	115	6	6	·742	121	3	20
·707	115	9	12	·743	121	7	3
·708	115	12	19	·744	121	10	9
·709	115	16	1	·745	121	13	6
·710	115	19	8	·746	121	16	22
·711	116	2	14	·747	122	0	4
·712	116	5	20	·748	122	3	11
·713	116	9	3	·749	122	6	17
·714	116	12	9	·750	122	10	0
·715	116	15	16	·751	122	13	6
·716	116	18	22	·752	122	16	12
·717	117	2	4	·753	122	19	19
·718	117	5	11	·754	123	3	1
·719	117	8	17	·755	123	6	8
·720	117	12	0	·756	123	9	14
·721	117	15	6	·757	123	12	20
·722	117	18	12	·758	123	16	3
·723	118	1	19	·759	123	19	9
·724	118	5	1	·760	124	2	16
·725	118	8	8	·761	124	5	22
·726	118	11	14	·762	124	9	4
·727	118	14	20	·763	124	12	11
·728	118	18	3	·764	124	15	17
·729	119	1	9	·765	124	19	0
·730	119	4	16	·766	125	2	6
·731	119	7	22	·767	125	5	12
·732	119	11	4	·768	125	8	19
·733	119	14	11	·769	125	12	1
·734	119	17	17	·770	125	15	8
·735	120	1	0	·771	125	18	14
·736	120	4	6	·772	126	1	20
·737	120	7	12	·773	126	5	3
·738	120	10	19	·774	126	8	9

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·775	126	11	16
·776	126	14	22
·777	126	18	4
·778	127	1	11
·779	127	4	17
·780	127	8	0
·781	127	11	6
·782	127	14	12
·783	127	17	19
·784	128	1	1
·785	128	4	8
·786	128	7	14
·787	128	10	20
·788	128	14	3
·789	128	17	9
·790	129	0	16
·791	129	3	22
·792	129	7	4
·793	129	10	11
·794	129	13	17
·795	129	17	0
·796	130	0	6
·797	130	3	12
·798	130	6	19
·799	130	10	1
·800	130	13	8
·801	130	16	14
·802	130	19	20
·803	131	3	3
·804	131	6	9
·805	131	9	16
·806	131	12	22
·807	131	16	4
·808	131	19	11
·809	132	2	17
·810	132	6	0

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*
·811	132	9	6
·812	132	12	12
·813	132	15	19
·814	132	19	1
·815	133	2	8
·816	133	5	14
·817	133	8	20
·818	133	12	3
·819	133	15	9
·820	133	18	16
·821	134	1	22
·822	134	5	4
·823	134	8	11
·824	134	11	17
·825	134	15	0
·826	134	18	6
·827	135	1	12
·828	135	4	19
·829	135	8	1
·830	135	11	8
·831	135	14	14
·832	135	17	20
·833	136	1	3
·834	136	4	9
·835	136	7	16
·836	136	10	22
·837	136	14	4
·838	136	17	11
·839	137	0	17
·840	137	4	0
·841	137	7	6
·842	137	10	12
·843	137	13	19
·844	137	17	1
·845	138	0	8
·846	138	3	14

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·847	138	6	20	·883	144	4	11
·848	138	10	3	·884	144	7	17
·849	138	13	19	·885	144	11	0
·850	138	16	16	·886	144	14	6
·851	138	19	22	·887	144	17	12
·852	139	3	4	·888	145	0	19
·853	139	6	11	·889	145	4	1
·854	139	9	17	·890	145	7	8
·855	139	13	0	·891	145	10	14
·856	139	16	6	·892	145	13	20
·857	139	19	12	·893	145	17	3
·858	140	2	19	·894	146	0	9
·859	140	6	1	·895	146	3	16
·860	140	9	8	·896	146	6	22
·861	140	12	14	·897	146	10	4
·862	140	15	20	·898	146	13	11
·863	140	19	3	·899	146	16	17
·864	141	2	9	·900	147	0	0
·865	141	5	16	·901	147	3	6
·866	141	8	22	·902	147	6	12
·867	141	12	4	·903	147	9	19
·868	141	15	11	·904	147	13	1
·869	141	18	17	·905	147	16	8
·870	142	2	0	·906	147	19	14
·871	142	5	6	·907	148	2	2
·872	142	8	12	·908	148	6	3
·873	142	11	19	·909	148	9	9
·874	142	15	1	·910	148	12	16
·875	142	18	8	·911	148	15	21
·876	143	1	14	·912	148	19	4
·877	143	4	20	·913	149	2	11
·878	143	8	3	·914	149	5	17
·879	143	11	9	·915	149	9	0
·880	143	14	16	·916	149	12	6
·881	143	17	22	·917	149	15	12
·882	144	1	4	·918	149	18	19

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
·919	150	2	1	·955	155	19	16
·920	150	5	8	·956	156	2	22
·921	150	8	14	·957	156	6	4
·922	150	11	20	·958	156	9	11
·923	150	15	3	·959	156	12	17
·924	150	18	9	·960	156	16	0
·925	151	1	16	·961	156	19	6
·926	151	4	22	·962	157	2	12
·927	151	8	4	·963	157	5	19
·928	151	11	11	·964	157	9	1
·929	151	14	17	·965	157	12	8
·930	151	18	0	·966	157	15	14
·931	152	1	6	·967	157	18	20
·932	152	4	12	·968	158	2	3
·933	152	7	19	·969	158	5	9
·934	152	11	1	·970	158	8	16
·935	152	14	8	·971	158	11	22
·936	152	17	14	·972	158	15	4
·937	153	0	20	·973	158	18	11
·938	153	4	3	·974	159	1	17
·939	153	7	9	·975	159	5	0
·940	153	10	16	·976	159	8	6
·941	153	13	22	·977	159	11	12
·942	153	17	4	·978	159	14	19
·943	154	0	11	·979	159	18	1
·944	154	3	17	·980	160	1	8
·945	154	7	0	·981	160	4	14
·946	154	10	6	·982	160	7	20
·947	154	13	12	·983	160	10	3
·948	154	16	19	·984	160	14	9
·949	155	0	1	·985	160	17	6
·950	155	3	8	·986	161	0	22
·951	155	6	14	·987	161	4	4
·952	155	9	20	·988	161	7	11
·953	155	13	3	·989	161	10	17
·954	155	16	9	·990	161	14	0

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.	Gr.	Oz.	Dwts.	Grs.
·991	161	17	6	28	4573	6	16
·992	162	0	12	29	4736	13	8
·993	162	3	19	30	4900	0	0
·994	162	7	1	31	5063	6	16
·995	162	10	8	32	5226	13	8
·996	162	13	14	33	5390	0	0
·997	162	16	20	34	5553	6	16
·998	163	0	3	35	5716	13	8
·999	163	3	9	36	5880	0	0
1 grain	163	6	16	37	6043	6	16
2	326	13	8	38	6206	13	8
3	490	0	0	39	6370	0	0
4	653	6	16	40	6533	6	16
5	816	13	8	41	6696	13	8
6	980	0	0	42	6860	0	0
7	1143	6	16	43	7023	6	16
8	1306	13	8	44	7186	13	8
9	1470	0	0	45	7350	0	0
10	1633	6	16	46	7513	6	16
11	1796	13	8	47	7676	13	8
12	1960	0	0	48	7840	0	0
13	2123	6	16	49	8003	6	16
14	2286	13	8	50	8166	13	8
15	2450	0	0	51	8330	0	0
16	2613	6	16	52	8493	6	16
17	2776	13	8	53	8656	13	8
18	2940	0	0	54	8820	0	0
19	3103	6	16	55	8983	6	16
20	3266	13	8	56	9146	13	8
21	3430	0	0	57	9310	0	0
22	3593	6	16	58	9473	6	16
23	3756	13	8	59	9636	13	8
24	3920	0	0	60	9800	0	0
25	4083	6	16	61	9963	6	16
26	4246	13	8	62	10126	13	8
27	4410	0	0	63	10290	0	0

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL			If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	*Oz.*	*Dwts.*	*Grs.*	*Gr.*	*Oz.*	*Dwts.*	*Grs.*
64	10453	6	16	100	16333	6	16
65	10616	13	8	101	16496	13	8
66	10780	0	0	102	16660	0	0
67	10943	6	16	103	16823	6	16
68	11106	13	8	104	16986	13	8
69	11270	0	0	105	17150	0	0
70	11433	6	16	106	17313	6	16
71	11596	13	8	107	17476	13	8
72	11760	0	0	108	17640	0	0
73	11923	6	16	109	17803	6	16
74	12086	13	8	110	17966	13	8
75	12250	0	0	111	18130	0	0
76	12413	6	16	112	18293	6	16
77	12576	13	8	113	18456	13	8
78	12740	0	0	114	18620	0	0
79	12903	6	16	115	18783	6	16
80	13066	13	8	116	18946	13	8
81	13230	0	0	117	19110	0	0
82	13393	6	16	118	19273	6	16
83	13556	13	8	119	19436	13	8
84	13720	0	0	120	19600	0	0
85	13883	6	16	121	19763	6	16
86	14046	13	8	122	19926	13	8
87	14210	0	0	123	20090	0	0
88	14373	6	16	124	20253	6	16
89	14536	13	8	125	20416	13	8
90	14700	0	0	126	20580	0	0
91	14863	6	16	127	20743	6	16
92	15026	13	8	128	20906	13	8
93	15190	0	0	129	21070	0	0
94	15353	6	16	130	21233	6	16
95	15516	13	8	131	21396	13	8
96	15680	0	0	132	21560	0	0
97	15843	6	16	133	21723	6	16
98	16006	13	8	134	21886	13	8
99	16170	0	0	135	22050	0	0

If 200 Grains of Ore give of FINE METAL	One Ton of Ore will yield of FINE METAL		
Gr.	Oz.	Dwts.	Grs.
136	22213	6	16
137	22376	13	8
138	22540	0	0
139	22703	6	16
140	22866	13	8
141	23030	0	0
142	23193	6	16
143	23356	13	8
144	23520	0	0
145	23683	6	16
146	23846	13	8
147	24010	0	0
148	24173	6	16
149	24336	13	8
150	24500	0	0
151	24663	6	16
152	24826	13	8
153	24990	0	0
154	25153	6	16
155	25316	13	8
156	25480	0	0
157	25643	6	16
158	25806	13	8
159	25970	0	0
160	26133	6	16
161	26296	13	8
162	26460	0	0
163	26623	6	16
164	26786	13	8
165	26950	0	0
166	27113	6	16
167	27276	13	8
168	27440	0	0
169	27603	6	16
170	27766	13	8
171	27930	0	0
172	28093	6	16
173	28256	13	8
174	28420	0	0
175	28583	6	16
176	28746	13	8
177	28910	0	0
178	29073	6	16
179	29236	13	8
180	29400	0	0
181	29563	6	16
182	29726	13	8
183	29890	0	0
184	30053	6	16
185	30216	13	8
186	30380	0	0
187	30543	6	16
188	30706	13	8
189	30870	0	0
190	31033	6	16
191	31196	13	8
192	31360	0	0
193	31523	6	16
194	31686	13	8
195	31850	0	0
196	32013	6	16
197	32176	13	8
198	32340	0	0
199	32503	6	16
200	32666	13	8

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